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ASSESSMENT OF THE METROLOGICAL PERFORMANCES OF A DELIVERY STATION

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ASSESSMENT OF THE METROLOGICAL PERFORMANCES OF A DELIVERY STATION.

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ABSTRACT

Gaz De France is leading an important research programme on the installation conditions of flow meters. As part of this programme we have made laboratory tests on a gas regulating/metering station (35 → 5 bar).

Two different turbine meters, a G650 (Qmax=1000 m3/h) and a G400 (Qmax=650 m3/h), have been calibrated and than tested in the delivery station. Large additional reading errors have been observed (in the order of ±3%) under normal working conditions.

We have then measured the axial and tangential velocity profiles at the meter location with a special self acting device. We have discovered the presence in the flow of strong perturbations that explain the meter reading errors. Some solutions have been recommended and successfully tested.

These tests highlight the necessity to improve the standards and to develop on-site diagnostic tools able to characterise the flow perturbations under real working conditions.

INTRODUCTION

In the gas metering stations the flow meters are often installed downstream of pressure regulators, single bends, double bends out-of-plane, diffusers, valves and other obstacles. The researches lead by all the gas companies in the past years have shown that each of these elements produces flow perturbations which turbine meters are sensitive to. In the delivery stations, the coupling of these various disturbing elements and the superposition of their effects can induce significant reading errors on turbine flow meters. In such conditions their calibration curve, obtained for ideal flow conditions, can no longer be considered as a reference.

Conscious of these problems, the gas companies and the regulatory authorities have established standards (AGA3, ISO9951, CEN/TC237, etc.) and internal recommendations that specify requirements and tests for the design and performance of gas meters and gas metering stations. the standards provide in particular standardised perturbation tests to assess the sensitivity of turbine gas meters to upstream installation conditions. These perturbation tests were supposed to represent the perturbations produced by piping elements such as bends, tees, convergent or divergent sections (low level perturbations), or those produced by regulators or other throttling devices (high level perturbations).

Although these standards, recommendations and perturbation tests had been adequate by the time they were established, They are no longer sufficient today. The gas regulating/metering stations are increasingly compact and the expansion ratios increasingly high,thus involving higher levels of perturbations. The standardised perturbation tests are no longer representative of the real installation conditions in such compact regulating/metering stations. The gas turbine meters that successfully go through the perturbation testing may still indicate large reading errors in those stations. This is demonstrated by the tests presented in this report.

The tests have been carried out on a gas metering station complying with ISO9951 and Gaz De France recommendations. Its geometrical configuration is one among the great variety of existing configurations. It has been selected because it shows the high levels of metering errors that gas companies are exposed to with nowadays compact installations. Two turbine meters, a G650 and a G400 have been calibrated in the station for various operating conditions. Velocity profile measurements have been completed to determine the flow conditions at the meters inlet and to understand their behaviour. Solutions have been provided.

EXPERIMENTAL SET-UP

Figure 1 shows the plan of the delivery station. It is a regulating/metering station designed for the operation on the transportation network. It comprises of two regulating lines and of one turbine meter. The main line, L1, is equipped with a "silent regulator" and the security line, L2, is equipped with a "standard regulator". The meter is installed 5.2 diameters downstream of the last bend, in a 150 mm bore section (6"). Under normal operating conditions the meter is fed by the main line equipped with the silent regulator.

Two turbine meters, a G650 (Qmax=1000 m3/h) and a G400 (Qmax=650 m3/h), have been tested in the station at an absolute pressure of 5 bar. The tests have been carried out in four phases:

Phase 1: Behaviour of the meters in the station for the normal configuration for two pressure ratios.
Phase 2: Behaviour of the G400 after inversion of the regulators.
Phase 3: Technical solutions.
Phase 4: Velocity profile measurements.

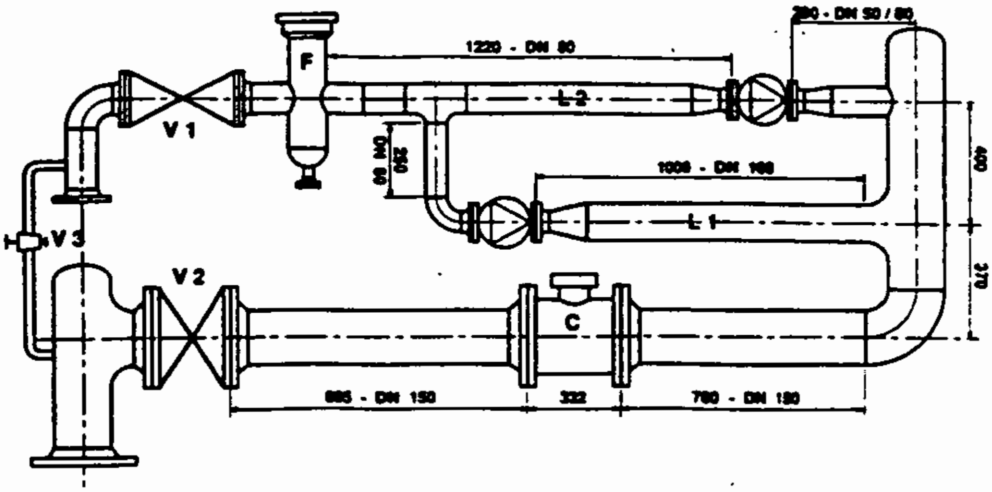


Figure 1 - Plan of the gas regulating/metering station

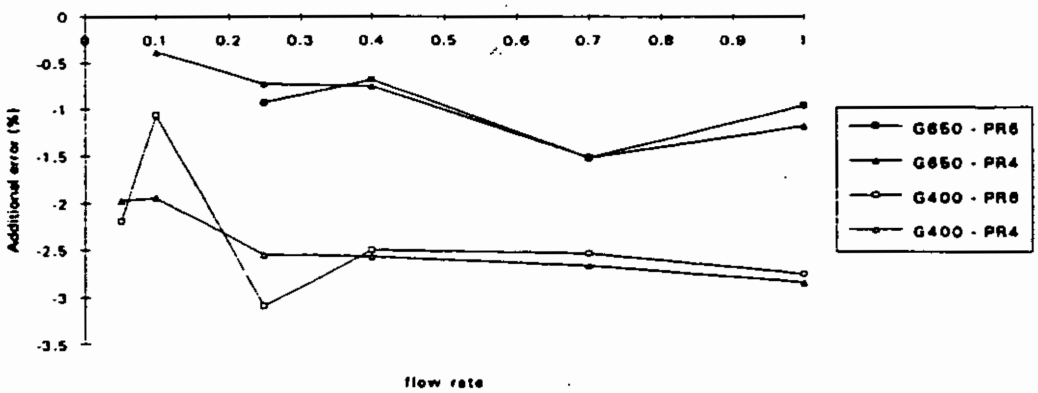
RESULTS AND DISCUSSION

Phase 1

We have tested each turbine meter at 5 bar (abs) in the station as originally configured: with the silent regulator in the main line and with the standard regulator in the security line, for each case two pressure ratios have been investigated: 6 and 4.

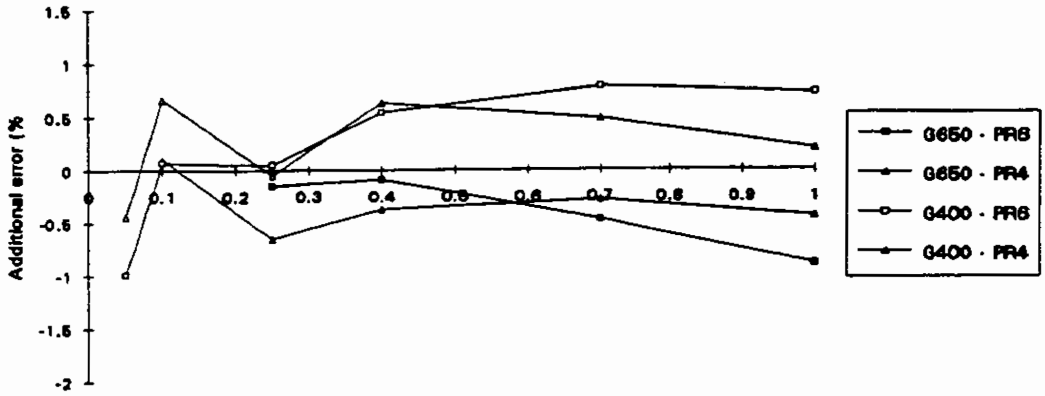
Figure 2 shows the additional error curves obtained for the two turbine meters under normal working conditions, that is when the main line is operating with the silent regulator. There is a strong influence of the installation conditions on the meters. The additional error, calculated with respect to the reference curve obtained for ideal flow conditions, varies between -1% and -1.5% for the G650 and between -1% and -3% for the G400. The pressure ratio does not have a significant influence on the metering accuracy.

Figure 2 - Silent regulator in main line



The additional error curves shown on figure 3 are obtained when the security line is operating with the standard regulator. In this configuration the metering is improved. The additional error of the G650 is reduced to 0% to -0.8% and the additional error of the G400 is reduced to -0.5% to 0.7%. Also, for this regulator the pressure ratio does not have a significant influence on the meter error.

Fig. 3 - Standard regulator in the security line



Below, table 1 summarises these tests giving the deviation. The deviation is the weighted mean additional error calculated according to the following formulae:

$$\text{deviation} = \frac{\sum_{i=1}^{n}(Q_i/Q_{max}) * E_i}{\sum_{i=1}^{n}(Q_i/Q_{max})}$$

where Q_i/Q_{max} is a weighting factor, E_i is the additional error of indication at the flow rate Q_i. For $Q_i = Q_{max}$ a weighting factor of 0.4 is taken instead of 1.

Table 1

Configuration	Silent regulator on main line		Standard regulator on security line	
Pressure ratio	6	4	6	4
deviation of G650	-1.03 %	-1.08 %	-0.40 %	-0.35 %
deviation of G400	-2.56 %	-2.61 %	0.54 %	0.37 %

Phase 2

From the results of phase 1 we have carried out more investigations by reversing the regulators in the station, in order to asses the influence of the type of regulator. The tests have been limited to the G400 and to the pressure ratio of 4. This new configuration places the silent regulator in the security line and the standard regulator in the main line.

The curves in figure 4 show the additional error of the G400 meter when the main line is operating. When the main line is equipped with the standard regulator, there is a large positive additional metering error for flow rates above 0.2 Qmax (+1.5% to +3.5%) and a large negative one for flow rates below 0.2 Qmax (-2% to -4%). Compared with the normal operating configuration (Silent regulator in the main line), there is still a strong influence of the installation conditions but the error is partially inverted. The sign of the error depends on the type of regulator.

Fig. 4 - Influence of the main line on the G400

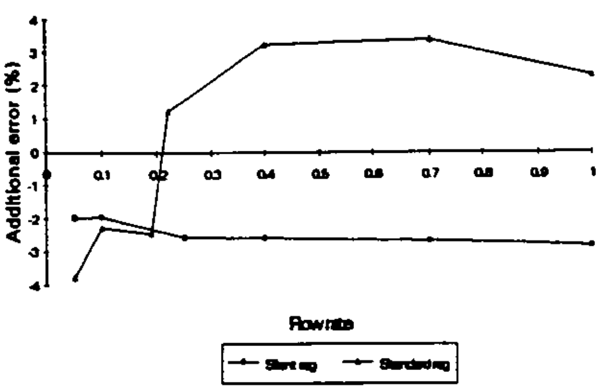


Fig. 5 - Influence of the security line on the G400

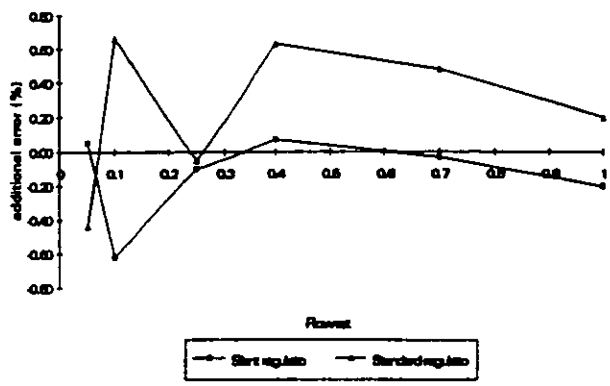


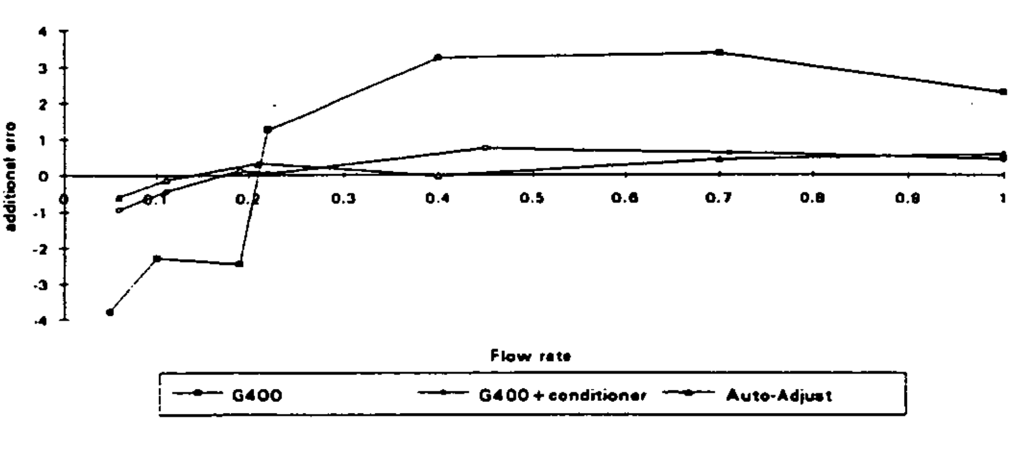
Figure 5 represents the results obtained with the security line operating. The same metering accuracy as for ideal flow conditions is achieved by operating the delivery station with the silent regulator in the security line.

A first conclusion can be drawn from these results: whatever the pressure regulator or the meter, the operation of the station by the main line involves large metering errors, whereas the operation by the security line involves comparatively small errors. The most influent factor is the geometry of the pipework upstream of the meter. However, when installed in the security line, the silent regulator gives better metrological performance than the standard regulator. A solution would be to use the line L2 as the main line equipped with the silent regulator.

<u>Phase 3</u>

Two other solutions have been tested and represented on figure 6: the use of a flow conditioner and of an Auto-Adjust turbine meter (twin rotor turbine meter).

Fig. 6 - Standard regulator in main line



The G400 was tested with the standard regulator mounted in the main line, with the flow conditioner directly connected to its upstream flange. The conditioner (see figure 7) consisted of a porous body joined to a short tube bundle. At 5 bar and for the maximum flow rate it generates a pressure loss of approximately 0.5 bar. The error of indication of the meter is significantly lowered and drawn back to an acceptable level.

In the same conditions the additional error curve obtained for the Auto-Adjust turbine meter shows a spectacular improvement of the metering accuracy, compared to the single rotor turbine meter G400.

Phase 4

To understand the results obtained in the first three phases and be able to relate the observed errors to the flow configuration, we have made some velocity profile measurements at the meter location. Figures 7 to 11 show the axial and tangential velocity profiles obtained when the station operates in its original configuration, shown in figure 1 (silent regulator in main line and standard regulator in security line) and downstream of the flow conditioner. Profiles have been measured in each case at 150 m3/h and at 450 m3/h for a pressure ratio of 4.

A velocity profile consists of measuring the axial and tangential velocity on four diameters at different angular positions (-45°, 0°,45° and 90°). 30 measurement points are taken per diameter. This is realised by a self acting device that automaticaly displaces a hot wire probe in the section. One profile measurement takes about 30 minutes. As it is difficult to have a perfectly stable flow rate during half an hour some profiles appear slightly distorded. A positive tangential velocity for the positive x and respectively negative for the negative x, indicates an anticlockwise swirl when looking at the flow coming and vice versa.

In all cases, except with the flow conditioner, the axial velocity profiles are almost symmetric, well developed and there is a fluctuating velocity rate of about 18% to 20%. With the flow conditioner the fluctuating rate is only 4% and the profile is perfectly symmetric. But the axial velocity is much higher on the edge of the section than in the centre. This is due to the shape of the tube bundle being concave and not flat. This might be the reason why the G400 slightly over counts for high flow rates downstream of the conditioner. A simple modification of the tube bundle's shape should improve this situation.

In the case of the main line equipped with the silent regulator there is a strong positive swirl of 18° at both flow rates, indicating a rotation of the flow in the opposite direction of the turbine wheel rotation. This decreases the speed of the wheel inducing a large negative error of indication (see figure 2).

In the case of the security line equipped with the standard regulator there is some swirl but relatively low compared to the previous case: 3° at 150 m3/h and 4° at 450 m3/h. This could be the reason for the slight negative error of the G650 but cannot explain the positive error obtained for the G400.

Observations made by the CERT/ONERA downstream of these two regulators have shown that the silent regulator mainly generates asymmetry whereas the standard regulator generates highly disturbed flows, mainly because of swirl. What is more, the direction of the swirl can vary according to the flow rate. That is probably why the error observed changes sign between the low and the high flow rates, when the main line operates with the standard regulator. Other profiles will be made in this previously mentioned set-up that will probably establish that for low flow rates the swirl is positive and that for high flow rates it is negative.

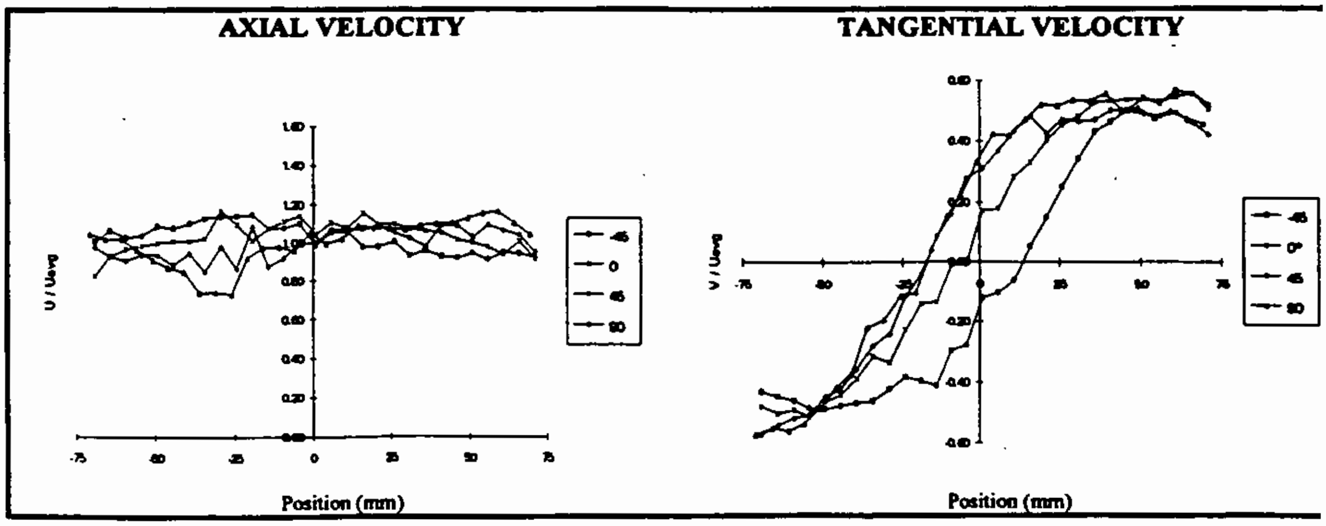


Fig 7: silent regulator in main line - 150 m3/h.

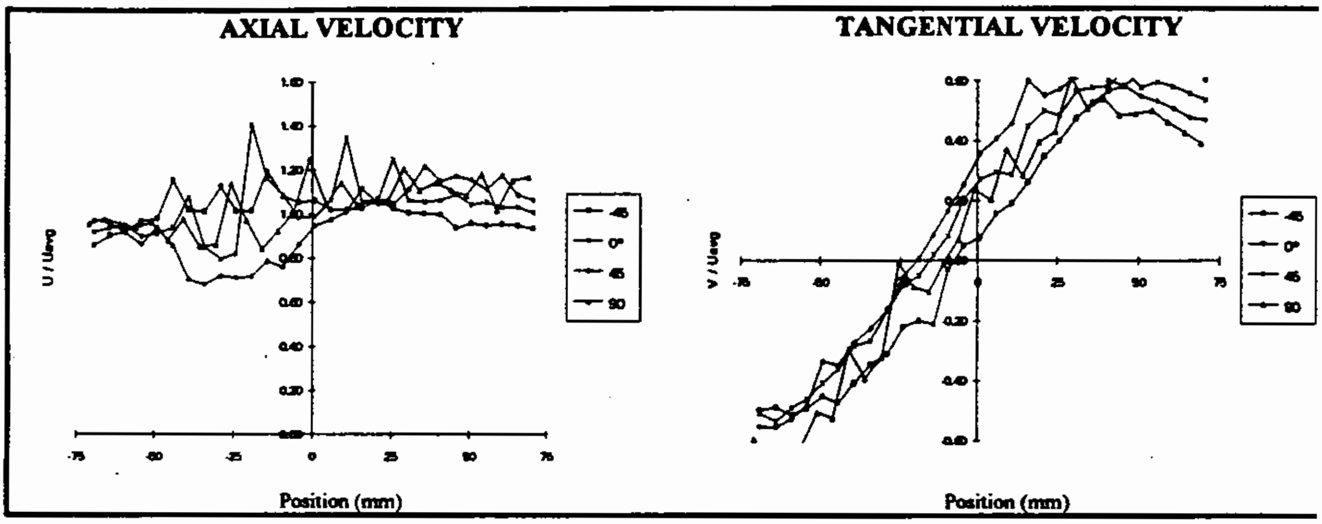


Fig. 8: silent regulator in main line - 450 m3/h

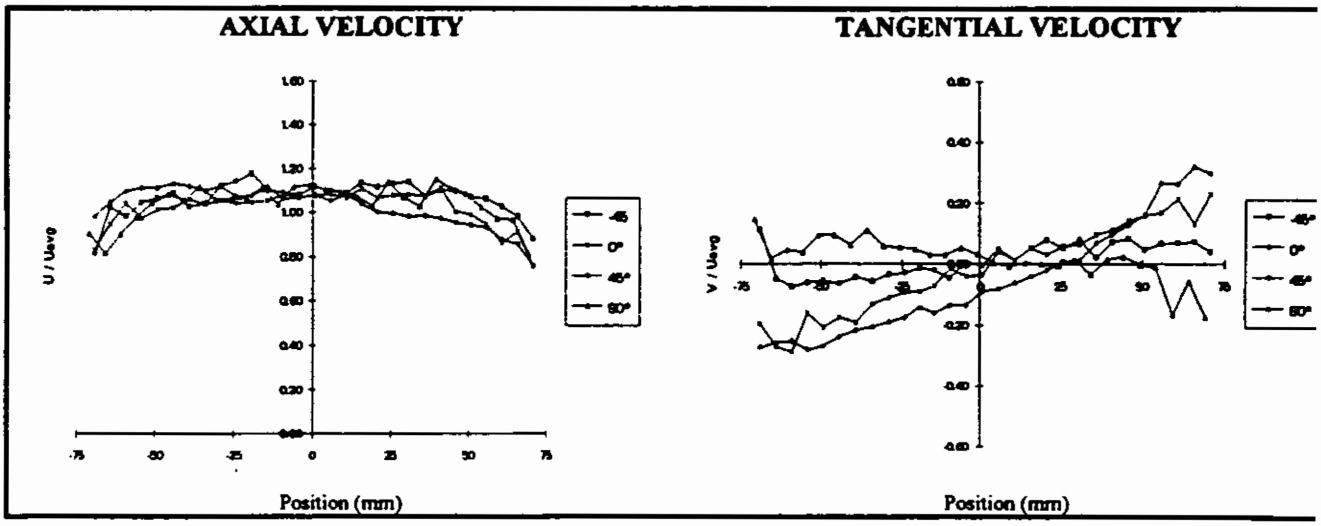


Fig 9: standard regulator in security line - 150 m3/h

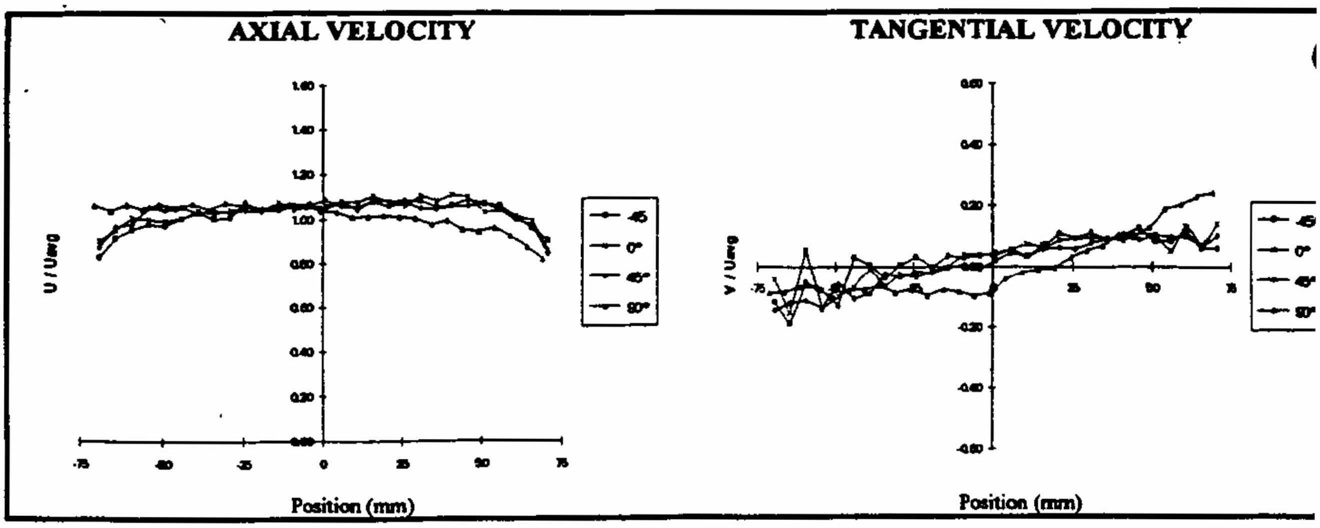


Fig 10: standard regulator in security line - 450 m3/h

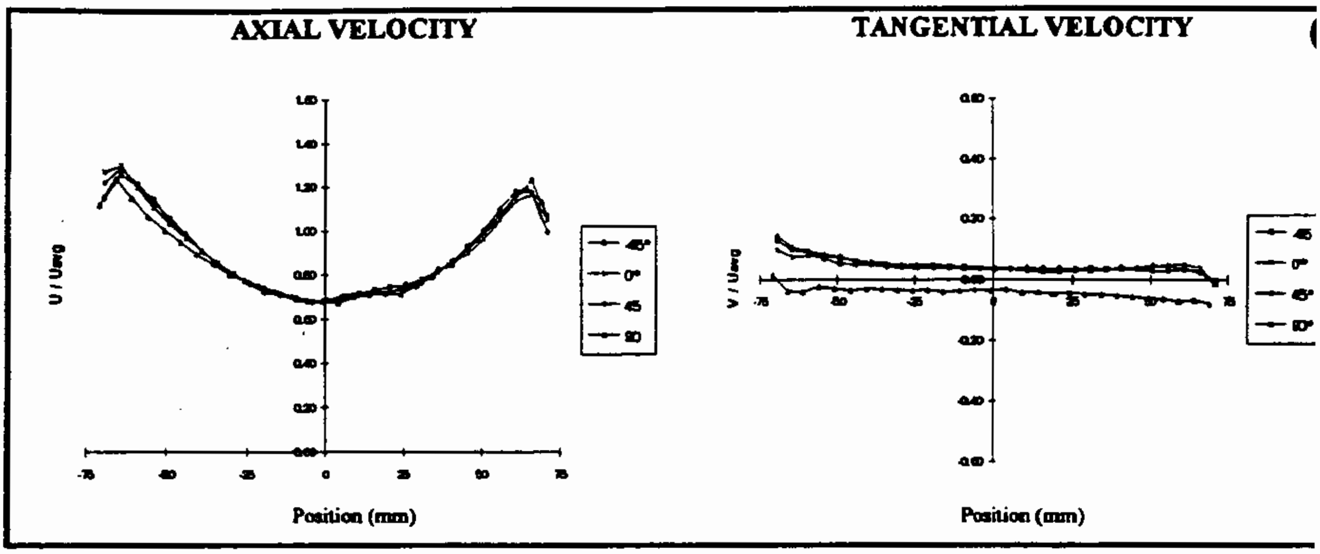


Fig 11: standard regulator in main line with flow conditioner - 450 m3/h

CONCLUSION

These calibration tests demonstrate that the standards and ISO perturbation tests no longer guaranty a good metrological quality. They have to be completed in order to take into account compact installation conditions such as the one we have tested, associating regulators and complex geometrical pipework. The compactness has become a inevitable requirement of modern gas metering stations. So there is an urgent need for the gas industry to find practical solutions, to meet their customers requirements

In order to guaranty the flow metering performance of the gas stations, the gas meter would have to be calibrated including the upstream pipework and the regulator. Because of the large number of existing installations and possible geometrical configurations, this is not possible in practice.

It is necessary to improve the existing standards or to establish new ones to provide precise guidelines for the design and the operation of future metering stations (this is being carried out by the CEN/TC234/WG5).

Concerning the existing metering stations, it is necessary to develop field tools able to measure and characterise the perturbation level at the meter and to provide simple solutions such as flow conditioners. These tests demonstrate that on-site diagnostic tools able to characterise the flow perturbations can help to predict the meter error and, if necessary, to find a solution.

Numerical simulations might also be in the future of great help to better understand the complex flow phenomena in the pipes and to design more compact stations. Their use will allow to reduce the number of tests and to predict the flow velocity profiles where it is difficult to measure them, for example in large stations for industrial customers where it is impossible to stop the gas supply.

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.