Main Index

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# INSTALLATION EFFECTS ON A MULTIPATH ULTRASONIC FLOW METER DESIGNED FOR PROFILE DISTURBANCES

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# INSTALLATION EFFECTS ON A MULTIPATH ULTRASONIC FLOW METER DESIGNED FOR PROFILE DISTURBANCES

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**Summary**

Previous work on ultrasonic flowmeters (as carried out within the "Ultraflow" project presented at North Sea Workshop in 1994) has demonstrated that, even with the use of multipath configuration, the design of an ultrasonic meter could be sensitive to profile disturbances. A complementary work, on a different design from that used in the "Ultraflow" project, was performed on a DN300 meter operating on natural gas at pressures from 15 to 60 bar. This kind of work is necessary for the developpement of the installation standards.

This paper is an extract from the final joint report and individual test results obtained on the test facilities of Gasunie, Ruhrgas and Gaz De France. The tests performed under ideal flow conditions allow the evaluation of meter stability over the range of flow velocity and the influence of gas pressure. The effects of upstream disturbances (1 bend 90°, double bends out-of-plane and pressure reduction) are presented.

## 1 - Introduction

Ultrasonic gas flow metering is quite a recent technique. This type of gas meters has been commercially available for nearly 8 years and is entering the European market. Some large gas companies have already bought these meters in view of operational use. The recent multi-path ultrasonic gas flow meter can be considered a promising alternative to turbine meters or orifice plates for accurate measurement of large volume flow.

In ideal flow conditions, all the multi-path ultrasonic gas flow meters run properly. In theory, upstream disturbances have little effect on the multi-path ultrasonic gas flow meter. Nevertheless, recent studies regarding the effect of installation conditions and presented last year at the North Sea Flow Measurement Workshop [1], reveal that metering with multi-path ultrasonic technique can be disturbed if the meter is installed with less than 10D[1] of straight pipe from the disturbing pipe configuration or dowstream of a pressure reducer. This project was carried out in the framework of "Ultraflow" on DN150 and DN300 meters using 4 paths equiped with two transducers which measure the transit time with and against the direction of gas flow.

The actual meter under test is a DN300 meter. Its flow range measurement is larger than the previous meters and the metering uses 5 paths with 3 single reflection and 2 double reflection paths covering the pipe area and designed to avoid the effects of flow profile disturbances on the measurement.

The testing of this 5 path ultrasonic flow meter is performed in an EGMG project in which the participants are Ruhrgas (RG), Gasunie (GU), Gaz De France (GDF) and the meter manufacturer. Ruhrgas acts as the project manager. The aim of this project is to qualify this meter in terms of repeatability, reproducibility, effects of pressure, effects of transducer exchange, and to perform a series of tests to demonstrate the effect on the meter of upstream disturbances such as asymmetries, swirl and fluctuations caused by different 90° bend, double bends out-of-plane configurations and pressure reduction. Although it was not expected that the meter would

[1] straight lenght of 10 diameter long

run properly, the 2D distance between the configuration and the meter was also investigated. Ideal flow calibrations with diffent pressure, under fully developed flow conditions, were performed on each test facility. These tests were used as a reference to determine the effects of the different configurations and to detect the difference between the test facilities.

The test programme was carried out on the high pressure flow metering facilities of the gas company participants from September 1994 to July 1995. The descriptions of the test benches and their calibration uncertainties are given in [2]. These uncertainties are in the order of 0.3 % for each test bench. The impact of 90° bend installed at different distances was investigated by Ruhrgas on the Lintorf high pressure test rig. The swirl effect tests in accordance with the provisions of ISO 9951 for turbine meter testing with different straight pipe lenght between the disturbance and the meter were carried out by Gasunie in the Bernoulli Laboratory in Westerbork. Tests with the ultrasonic flowmeter turned on its longitudinal axis and transducers exchange tests were also carried out in both laboratories. Gaz De France completed the tests with the meter situated dowstream of a pressure reducer with and without a noise reducing part, and tests with the meter situated upstream of the pressure reducer. Table 1 shows all test configurations examined by the participants.

| Test | | Laboratory |
|---|---|---|
| **Ideal calibration** | 15 bar | RG, GDF |
| | 25 bar | RG, GDF |
| | 50 bar | RG |
| | 60 bar | GU |
| Transducers exchange | 15 bar | RG |
| | 60bar | GU |
| **Perturbation 90° single bend** | | |
| Distance 10D / 0° and 54° | 15 bar | RG |
| | 25 bar | RG |
| | 50 bar | RG |
| Distance 5D / 0° and 54° | 15 bar | RG |
| | 25 bar | RG |
| Distance 2D / 0° and 54° | 15 bar | RG |
| | 25 bar | RG |
| | 50 bar | RG |
| **Perturbation 180° double bend** | | |
| Distance 10D LL / 0° and 54° | 60 bar | GU |
| Distance 10D HL / 0° and 54° | " | GU |
| Distance 5D LL / 0° and 54° | " | GU |
| Distance 5D HL / 0° and 54° | " | GU |
| Distance 2D LL / 0° and 54° | " | GU |
| Distance 2D HL / 0° and 54° | " | GU |
| Distance 10D HL / -54° | " | GU |
| **Perturbation due to pressure reduction** | | |
| 5D downstream with noise reducer | 15 bar | GDF |
| 5D downstream without noise reducer | 15 bar | GDF |
| 5D upstream with noise reducer | 15 bar | GDF |

*TABLE 1 : test programme divided between laboratories*

## 2 - Description of the meter

The operating principle of the ultrasonic meter is based on the transit time method with direct digitising of each individal sound impulse. The flow meter under test has a 5 path configuration with 3 single reflection "axial" paths and 2 double reflection "swirl" paths in and against the direction of the flow. In this way, it is possible to pick up swirl effects in the flow and correct them by calculation. The housing diameter is 306 mm. The maximum flow rate is defined as 8000 $m^3/h$, i. e. the size of the meter is G5000 (maximum gas velocity = 30 m/s). This is twice larger than turbine meters of the same size. The minimum flow rate can be considered very low because there are no friction effects occuring at low flow rate on the metering as on volumetric meters. Its maximum pressure is 80 bar.

## 3 - Test configuration

The "ideal" calibration tests were performed prior to the disturbance tests. On each facility, the meter was installed with a large length of straight pipe upstream (at least 20D) and at different pressures. The calibrations were carried out with the meter installed horizontal with original transducers. The same hardware and parameters set-up were used throughout the programme with the exception of the density value at Westerbork.

The swirl disturbance consists of 2 bends out-of-plane as described in ISO 9951 for turbine meter testing. The flow upstream of this configuration is stabilised by a flow straightener. The asymmetric flow caused by the first bend is turned into a swirl by the second bend. The selected configuration creates an anti-clockwise so called "Low Level" swirl (LL). To create "High Level" swirl (HL), a half moon plate is installed between the two bends. The swirl produced is also anti clockwise but the swirl angles are approximately 2 to 3 times larger than for the "Low Level" swirl. The "Low Level" should represent the worst swirl disturbance in normal piping. The meter has been tested with 2D, 5D and 10D of straight pipe lenght between the swirl configuration and the inlet of the meter at a pressure of 60 bar. The tests were carried out with the meter mounted horizontally (noted 0°) and turned to 54° on its own axis.

The impact of asymmetric flow created by a 90° bend installed at distances of 2D, 5D and 10D upstream of the meter was investigated at three pressures of 15, 25 and 50 bar. The meter was first installed in a horizontal position (noted 0°) and rotated 54° from its body axis.

The influence of the exchange of transducers and electronics unit on fully developped flow profile was studied. This represents the case where the meter has one or more damaged transducers which have to be replaced. The question was whether the basic calibration is still valid with exchanged transducers. These test series were performed with one pair of extra transducers which replaced 2 transducers in various combinations.

The programme was completed with the test series of high level disturbances created by a pressure reducer. The pressure reducer used for these tests was a RMG axial flow regulator, the nominal diameter of which is DN80. It could be mounted with a noise reducer part, resulting in DN300. The necessary adapter parts were specially designed for the tests to join the regulator and the noise reducer to the pipes. Tests were carried out with the ultrasonic flow meter situated dowstream (5D) of the pressure reducer with and without the noise reducing part, and with the meter situated upstream of the pressure reducer (5D). For each of the three configurations, 1 test were carried out with a pressure reduction of 5 bar from 25 to 20 bar and from 20 to 15 bar, together with the test with the pressure reducer fully opened.

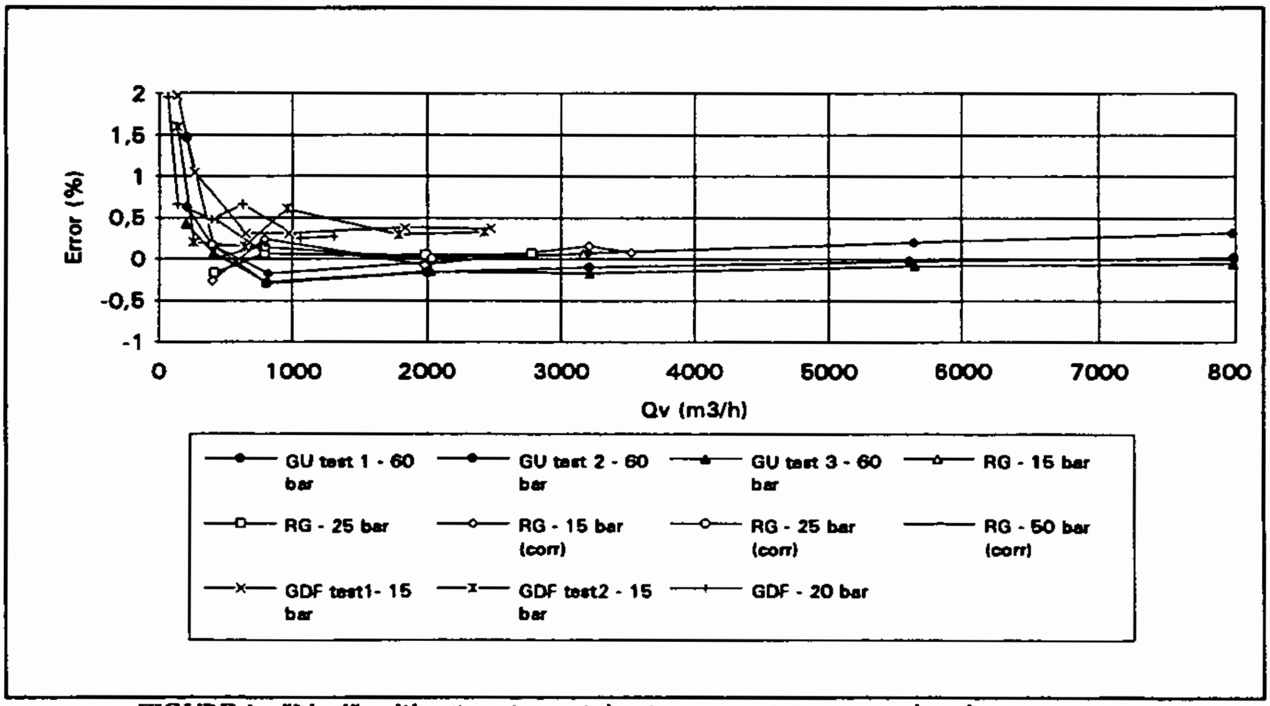


*FIGURE 1 : "Ideal" calibrations in straight pipe on participants test bench*

## 4 - Tests on ideal conditions

### 4.1 - Results of the ideal calibration tests

For the "ideal" calibration test, Gasunie carried out 3 calibrations at 60 bar, before and after the double bend tests and at the end of its programme. The Ruhrgas and Gaz De France error curves were measured with the meter mounted under ideal conditions at 15 and 25 bar before their test programme. Figure 1 shows the mean results of these test series.The meter was tested over a period of 10 months without any noticeable long term variation in calibration.

The overall spread of results between the benches is within ± 0.5 % taking into account individual points on the flow range from 10 to 100 % of the maximum flow rate and within ± 1 % from 5 to 10 %. Morever, the mean values are within ± 0.3 % on the flow range from 10 to 100 % of the maximum flow rate. Here, the calibration curves remain within the permissible error defined by legislations as ± 1 % for the flow rate between 20 % and 100 % of the maximum flow rate and ± 2 % for the flow rate between 5 % and 20 % of the maximum flow rate.

The spread of the results also includes the effect of temperature (from 10 up to 21 °C), differences in natural gas composition (Groningen, Norway, Algeria etc.), transportation of the meter and its instrumentation and small differences in "ideal" calibration installation. Morever, a slight change in flow profile due to a different pipe roughness could explain some differences noticed on the Gasunie calibration tests. The pipe wall of the meter had been cleaned after an inspection between test 1 and test 2.

The influence of the test pressure on the meter error is negligible. The mean influence of the pressure is 0.08 % on the Ruhrgas calibration curve and the maximum variation of the mean error values is less than 0.4 % on the Gaz De France results except at the lowest test flow rate for which the variation reaches 1.3 %. Figure 1 shows the maximum difference between the 15, 25 and 60 bar laboratories' curves of nearly 0.75 % on the flow range from 5 to 100 % of the maximum flow rate.

At very low flow rates, the mean error is positive and shows more scattered values. The individual values of the meter error are much more scattered at low flow rates than at high flow rates. Table 2 presents the standard deviations calculated from the meter error obtained by the three laboratories on low and large flow rate. The standard deviation is generally below 0.1 % which proves a good repeatability of the metering system, except for the lower flow rates. The explanation for the large variation of the meter error at low flow rates (from less than 1 up to 5 % of the maximum flow rate) could be the sudden or gradual change of the velocity distributions obverved. This effect disapeared at higher flow rates due to the turbulence regime.

**GASUNIE**

| Qv (m3/h) | σ(error) |
|---|---|
| 810 - 8000 | 0.01 |
| 400 | 0.05 |
| 200 | 0.14 |

**Pressure test = 60 bar**

**RUHRGAS**

| Qv (m3/h) | σ(error) |
|---|---|
| 800 - 3000 | 0.05 |
| 400 | 0.12 |

**Pressure test = 15 and 25 bar**

**GAZ DE FRANCE**

| Qv (m3/h) | σ(error) |
|---|---|
| 630 - 2500 | 0.05 *** |
| 400 | 0.04 ** |
| 260 | 0.31 * |
| 135 | 0.50 *** |
| 65 | 0.65 ** |

* Pressure test = 15 bar
** Pressure test = 25 bar
*** Pressure test = 15 and 25 bar

*Table 2 : standard deviations of the meter error*

During one test, the flow rate was increased at 145 % of the maximum flow rate to observe meter behaviour at very high flow rate. Some of the transducer signal was lost but since 60 % of the signals were accepted, the meter output is still reliable. The mean error was at this flow was + 0.33 %. Morever, some results were obtained for a very low flow rate down to 1 % of the maximum flow rate. The mean results are in the maximum permissible error although some individual values are out but still within ± 3 %.

#### 4.2 - Exchange of transducers and electronics unit

The results of tests for which transducers and electronics unit positionned on the meter body were exchanged proved that there is no influence. The deviations between the straight pipe calibration with the original transducers and the calibrations with the meter equipped with an extra pair of transducers are always within ± 0.2 % of the mean values on the flow range from 10 to 100 % of the maximum flow rate.

## 5 - Results of the disturbance tests

#### 5.1 - Perturbation 90° single bend

The results of the tests with a 90° bend installed upstream of the ultrasonic meter at a distance of 5D and 10D are presented in figure 2. It shows that the 10D straight lenght between the configuration and the meter gives acceptable results. The deviation of the meter error is less than 0.3 % for the measuring range from 10 to 100 % of the maximum flow rate. This deviation is within the ISO 9951 tolerance. The 5D distance results give a deviation of the measurements of - 0.7 % in the flow range from 10 to 100 % of the maximum flow rate. There is no significant influence of the pressure test on the metering system with both configurations.

The deviation of the meter error due to the 54° rotation of the meter on the 10D configuration is less than 0.1 %. It reaches nearly 0.2 % for the 5D configuration tests. These values do not deviate significantly from zero.

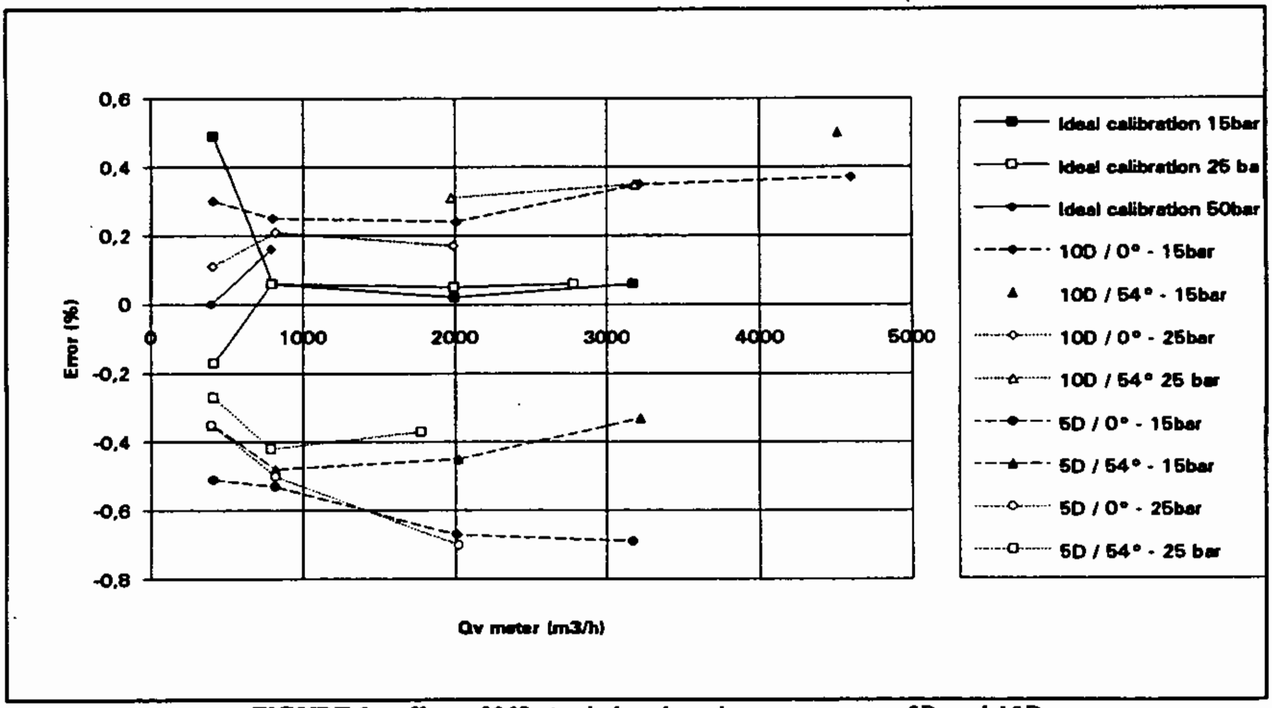


*FIGURE 2 : effect of 90° single bend on the meter error : 5D and 10D*

As presented in figure 3, the reduced straight length of 2D produced a considerable negative drop of the meter error curves. For all the pressure tests, the deviation of the error is roughly -2.0 % compared with the ideal calibration in large straight pipe length. The rotation of the meter on its body axis reduced the mean negative deviation close to the ideal calibration values. The influence of the pressure (15, 25 and 50 bar) is very low except near 400 $m^3/h$ for which the deviation reaches 0.5 %.

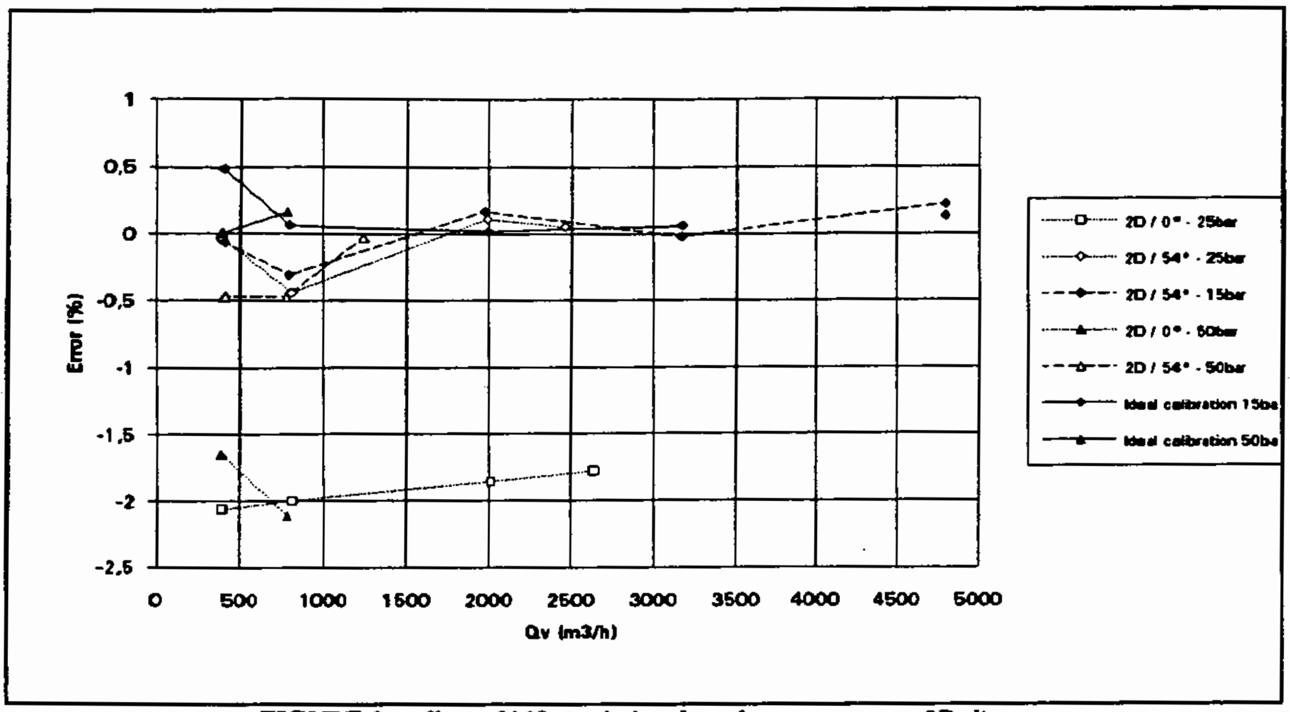


*FIGURE 3 : effect of 90° single bend on the meter error : 2D distance*

**5.2 - Perturbation double bends out of plane**

The curves of mean values in Low Level disturbance (LL) are presented in figure 4. The tests on swirling conditions prove that the results are more scattered than the test points of one particular test than the ideal calibration. At 2D distance, the error curves lie outside the defined error limits and show clearly the influence of the meter rotation. In the 5D and 10D, the curves are within the limits but there are slight differences caused by rotation of the meter.

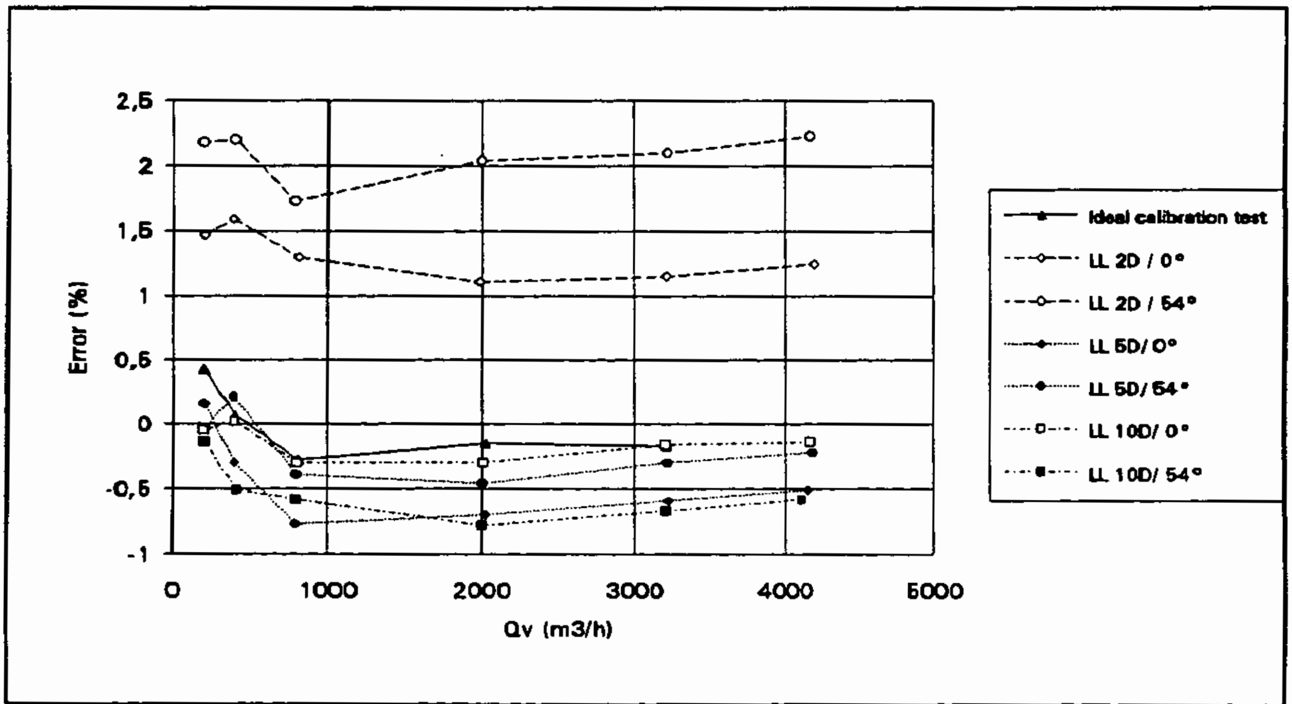


*FIGURE 4 : effect of LL disturbance created by double bends out of plane on the meter error*

Figure 5 presents the mean results obtained for the High Level disturbance tests (HL). For both 2D and 5D curves, there is a great difference between the horizontal (0°) and the rotation meter (54°) curves. Morever the results are more scattered than the Low Level values. At 10D, the curves lie within the the error limits but there is still some influence from the rotation of the meter. One of these curves is obtained with the meter rotated anti-clockwise on the axial position whereas the other rotation curves are obtained with the meter rotated clockwise.

At 2D distance, both Low and High Level disburbance may influence the meter reading and result in an uncceptable meter error, depending on the meter orientation. Nevertheless, the meter kept the signal in "High Level" pulsating flow. At 5D this effect vanished for the Low Level swirl but is still present for High Level disturbance. At 10D the meter errors are within the acceptable limits although dependent on the meter orientation.

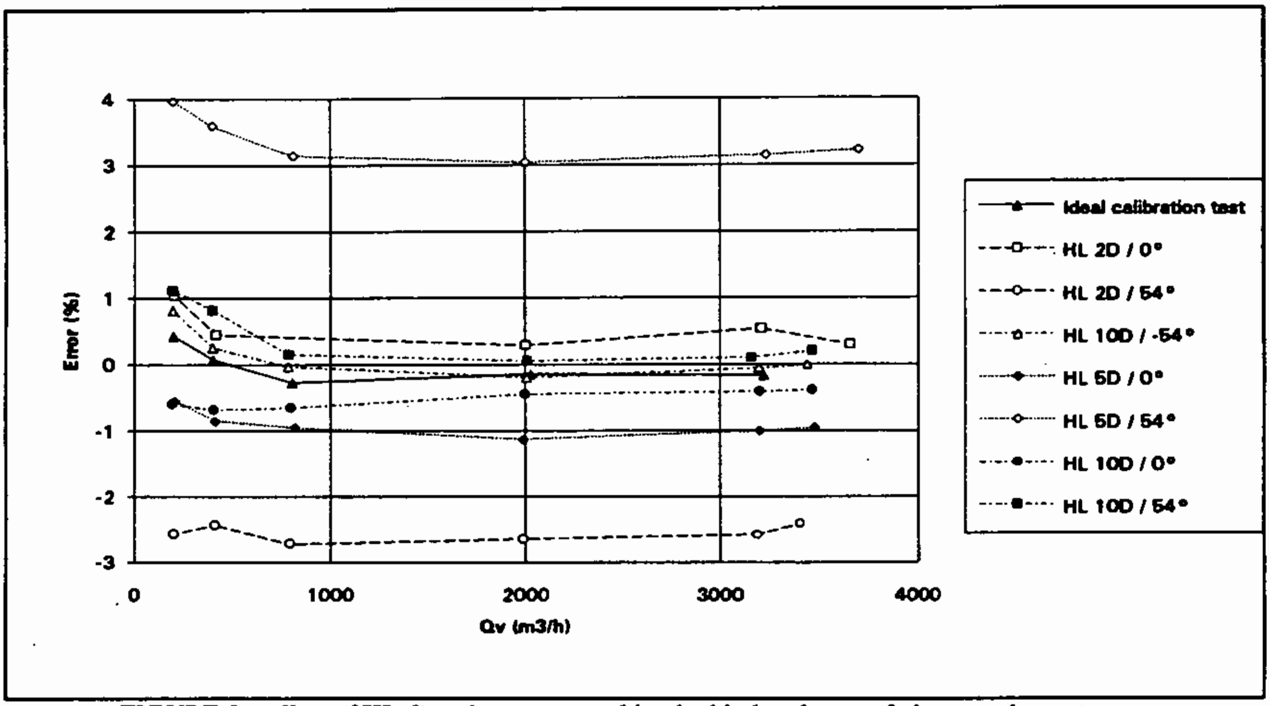


*FIGURE 5 : effect of HL disturbance created by double bends out of plane on the meter error*

**5.3 - Perturbation due to pressure reduction**

Only the tests with the pressure reducer fully opened or with the meter installed upstream of the regulator were completed. For the tests carried out with the meter installed dowstream of the regulator with a pressure reduction of 5 bar, the meter did not function at all for the two configurations and then the tests were aborted. Morever, with the same configuration and the pressure reducer fully opened, the meter did not operate correctly when the pressure reduction was in excess of 2 bar, except at very low flow rate. In some other cases, some of the 5 paths delivered an error signal which increased significantly the error of the meter.

The profile measurements recorded just upstream of the meter proved that the axial pressure reducer subjected the meter to a fully developed velocity profile with a high turbulence rate. Morover, during the test series, a very high noise was heard close to the regulator which gave us to believe that the meter was submitted to ultrasonic noise.

The results of the meter placed dowstream of a pressure reducer with and without its noise reducing part are presented in figure 6. Figure 7 shows the results with the meter mounted upstream of the pressure regulator with its noise reducer.

For a flow rate higher than 1000 $m^3/h$, the multipath ultrasonic flow meter is seriously affected by the presence of a pressure reducer installed upstream of the meter even if it is fully opened. For a pressure reduction of 5 bar, when the pressure reducer is installed downstream of the meter, the meter error became very high.

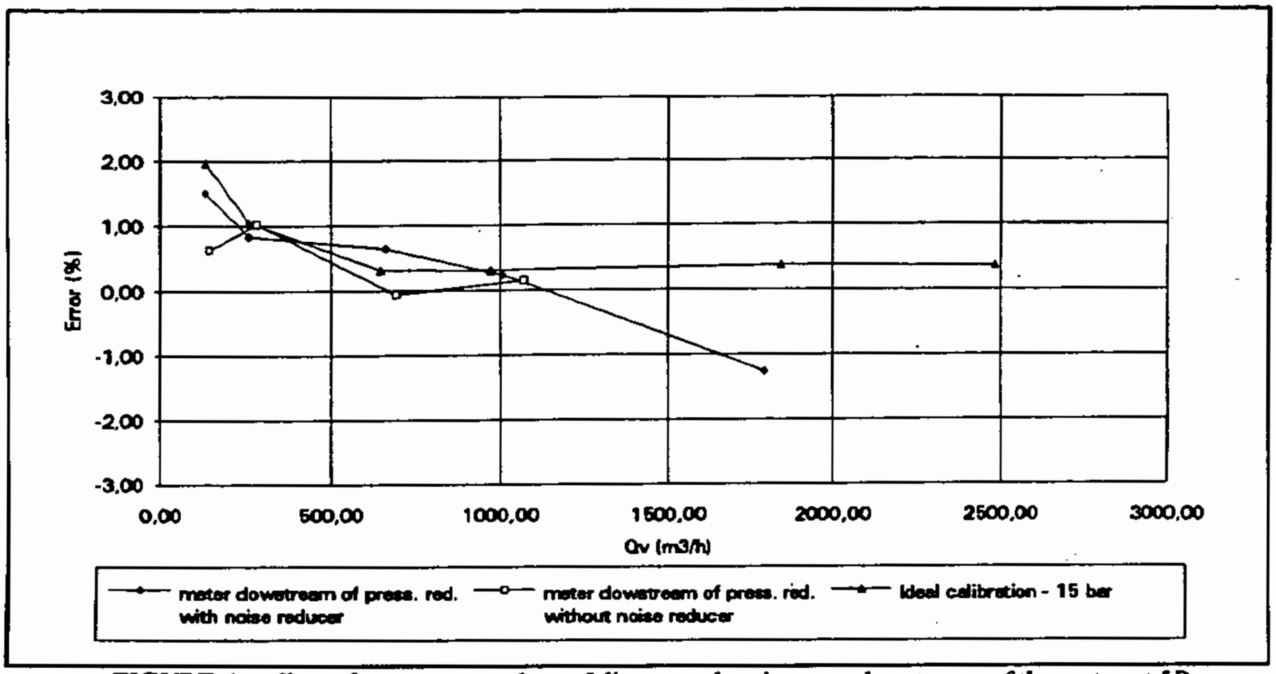


*FIGURE 6 : effect of a pressure reducer fully opened and mounted upstream of the meter at 5D*

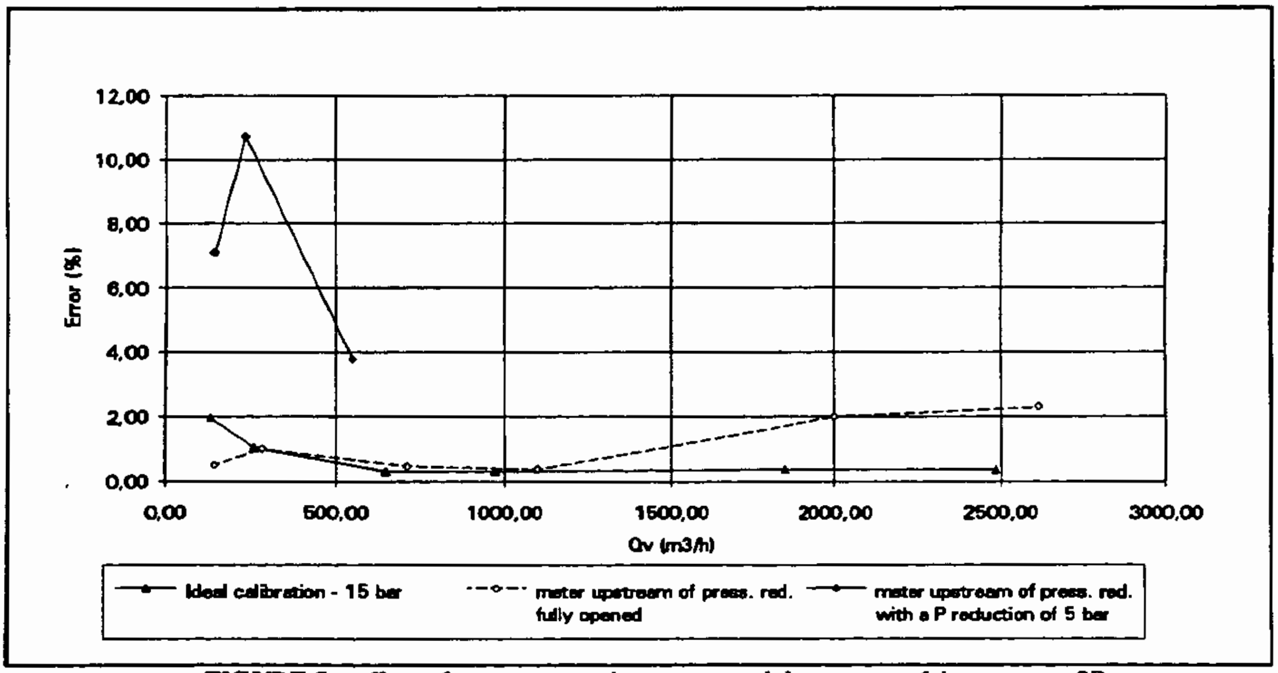


*FIGURE 7 : effect of a pressure reducer mounted dowstream of the meter at 5D*

## 6 - Conclusions

The maximum flow rate of the multipath ultrasonic flow meter is 8000 $m^3/h$ which is twice the metering capacity of a turbine meter of the same size.

The exchange of 2 transducers or of the electronics unit has no significant influence on the meter performance.

All the individual calibration values obtained in ideal conditions were spread within ± 0.5 % on the flow range from 10 to 100 % of the maximum flow rate and within ± 1 % from 5% to 10 %. Morover, the mean results are spread within ± 0.3 % on the flow range from 10 to 100 % of the maximum flow rate and then are within the maximum permissible error range. Morever, some results were obtained for a very low flow rate down to 1 % of the maximum flow rate with a maximum error of 3 %. During the very high flow rate test (145 % of the maximum flow rate), the meter output was still reliable and the mean error was + 0.33 %.

The deviations obtained for the test of 10D distance 90° single bend are within the ISO 9951 tolerance. The influence of a clockwise rotation of the meter is still acceptable. The reduction of the distance between the single bend and the meter to 5D led to a mean shift of -0.7 % which is outside the ISO tolerance for the range from 10 to 100 % of the maximum flow rate. Nevertheless, the error curve for the 5D test is within the maximum permissible errors. The effect of the 2D distance is very great and the meter error is outside the maximum permissible error.

The 2D distance for the low level disturbance configuration may result in unacceptable error. The 5D and 10D distance between the double bends and the meter give acceptable results although some slight effects of the rotation of the meter still exist. The high level swirl causes great deviation of the meter error both at 2D and 5D distances. At 10D, the error shifts are within the acceptable limits (± 0.5 %) but are still slightly dependent on the orientation.

The installation of the meter close to a RMG pressure reducer (5D distance) is unacceptable without provisions to eliminate ultrasonic noise and other disturbances. Only slight pressure reduction (less than 1 bar) dowstream of the meter could be allowed. This conclusion may not be representative for other types of pressure reducers.

Some additional uncertainties on the ultrasonic flow meter due to disturbances are proposed in table 3 regarding the distance between the pipe configuration and the meter. All figures are given in percentages taking into account that the orientation of the meter is not defined.

| | **Ideal calibration** | **90 ° bend** | | **LL swirl** | | **HL swirl** | | **Pressure reducer** |
|---|---|---|---|---|---|---|---|---|
| distance | > 20D | 5D | 10D | 5D | 10D | 5D | 10D | 5D |
| 5 paths meter | 0.5 | 0.7 | 0.3 | 1.0 | 1.0 | 3.5 | 1.0 | Unacceptable |

*TABLE 3 : summary of proposed additional uncertainties due to disturbances*

**Acknowlegments**

Thanks to all who contributed to the EGMG project by discussions and by carrying out the tests.

**References**

[1] K. van Bloemendaal and P. M. A. van der Kam, Installation effects on multi-path ultrasonic flow meters : the "Ultraflow" project, The North Sea Flow Measurement Workshop, 1994

[2] GERG / Intercomparaison Exercise of High Pressure Test Facilities within GERG, GERG TM6, 1993

[3] ISO 9951 / Measurement of Gas Flow in Closed Conduits - Turbine meters. 1993