North Sea FLOW Measurement Workshop

nel technology for life

Paper 3.2

Evaluation of Flow Conditioners – Ultrasonic Meters Combinations

Bruno Delenne
Gaz de France

Gerard Mouton
GSO

Michael Pritchard
Advantica

Michael Huppertz
Fluxys

Kristof Ciok
GASTRA

Aermout van den Heuvel
Gasunie Research

Trond Folkestad
Norsk Hydro

Detlef Vieth
Ruhrgas

Francisco Lezuan
ENGAS S.A.

Guiseppe Marini
Snam Rete Gas

EVALUATION OF FLOW CONDITIONERS - ULTRASONIC METERS COMBINATIONS

B. Delenne, Gaz De France
M. Pritchard, Advantica
F.J. Lezaun, Enagas
D. Vieth, Eon-Ruhrgas
M. Huppertz, Fluxys
K. Ciok, Gastra
A. van den Heuvel, Gasunie Research
G. Mouton, Gso
T. Folkestad, Norsk Hydro
G. Marini, Snam Rete Gas

1 INTRODUCTION

Despite very promising advantages, the spread of ultrasonic meters (USM) on European gas networks remains relatively modest. In Europe it seems that this technology still has to show good performances before being fully and widely accepted for fiscal gas metering in new metering stations or renovations, one major concern for network operators being a possible sensitivity to installation conditions. However, ultrasonic flow meters present a very worthwhile metering alternative and the technology is improving continuously. In this context, ten European gas companies agreed to work together within the GERG (Groupe Européen de Recherches Gazières) and to focus on the condition of installation and more especially on the possibility of coupling ultrasonic meters with flow conditioners (FC) to improve overall performance.

The scope of the project consists in assessing the performances of ultrasonic meters from market leaders downstream of representative piping configurations with and without flow conditioners. The objective is to provide a data set showing the performance of specific flow conditioner-flow meter combinations under various flow perturbations that could form a basis for installation recommendations. Several kinds of flow conditioners were used, among them also the recommended configurations proposed by the manufacturers. Similar investigations have already been carried out and the results have been published [1]. The objective of this project was to supplement the data available in the literature and to update the data base with regard to the most recent progress in ultrasonic meters technology.

2 THE TEST PROGRAMME

The test programme has been defined to assess the ability of ultrasonic meters to handle flow perturbations based on experimental work. The performances of different ultrasonic flow meters have been investigated with a variety of different flow conditioners located downstream of several piping configurations that generate flow disturbances. The results presented in this paper concern meters in DN200, which were evaluated on Bishop Auckland facilities.

2.1 Meters under test

The first step of this project consisted in selecting the meters to be tested. The GERG partners agreed to focus on most widespread multipath ultrasonic meters from market leaders, all being type approved in European countries:

- **Daniel Senior Sonic**,
- **FMC MPU 1200**,
- **Instromet Q.Sonic-4**.

The meters were lent to GERG by the manufacturers. It has to be mentioned that Daniel and Instromet delivered their absolute newest products that reflect their current technology (in the early 2004). Instromet equipped their meter with the new series IV electronics and software and a new integration technique, which should better correct for flow perturbations. Daniel changed somewhat the transducer and path design (different path angles). The meter from Daniel is the first of its kind in what is expected to be their new standard 8" meter. The most recent algorithms were also implemented in the meter provided by FMC but the spool piece was an older design, the angles on several paths have been optimised on new design for high flow velocity performance.

The Senior Sonic [2] and the Q.Sonic-4 [3] both have four paths, the MPU 1200 [4] has six paths. However the path arrangements of Daniel and FMC are comparable (direct and parallel paths), while Instromet design is based on a more complex arrangement with single and double reflecting paths. Individually, as each flow path velocity is likely to be affected by flow disturbances, each manufacturer has developed his own weighing and compensation algorithm to derive the flow rate from the information provided by each path. The methodology implemented by Daniel has been published [5], while FMC and Instromet regard this as confidential part of the metering software. For this project, the manufacturers have provided meters from their standard production series.

2.2 Flow conditioners used

Beyond the purpose of assessing the ability of ultrasonic meters to compensate for flow perturbations, one major objective of this project was to estimate the possibility of coupling ultrasonic meters with flow conditioners. As a matter of fact, despite the use of multiple paths and the use of elaborated weighting methods, ultrasonic meters are still likely to be influenced by flow perturbations. Flow perturbations require quite long lengths of straight pipe before vanishing naturally and flow conditioners are mentioned in several metering standards and in the literature as a possible solution to reduce this length. The main effect expected from using a flow conditioner is to eliminate the main components of the flow perturbations (swirl, asymmetry…) and above all to generate a consistent flow profile irrespective of upstream flow conditions.

Two flow conditioners have been selected and were installed 10D upstream the meters under test:

- **The Gallagher flow conditioner (GFC)** [6] that consists of two separate elements: a multi bladed component to be installed upstream of a perforated plate. The spacing between both components is 5D.
- **The CPA 50E** perforated plate [7], manufactured by CPACL in close relation with K-Lab. It is a perforated plate with 25 holes.

In addition to these flow conditioners, the ultrasonic meters manufacturers have been asked to define a recommended configuration with flow conditioners, i.e. their favourite flow conditioner and the corresponding condition of installation. FMC recommended to use the CPA 50E installed 10D upstream the meter, which was a configuration already chosen within the test programme. The additional flow conditioners tested are:

- **Profiler**: A perforated plate with 32 holes manufactured by Emerson Process Management [8]. The Profiler is recommended by Daniel to be installed 10D upstream of the Senior Sonic.
- **Instromet FS-3**: The Spearman perforated plate has been initially designed by NEL, it is recommended by Instromet [9] who made some slight modifications. Following Instromet's recommendation, this flow conditioner has been tested systematically 3D upstream of the Q.Sonic-4. The package, Instromet FS-3 installed 3D upstream of the Q.Sonic-4 has PTB approval for the use with 5D upstream length (minimum distance perturbation - USM).

2.3 Piping configurations

2.3.1 Straight line tests

Before submitting the meters to any flow disturbances, baseline tests have been performed. The meters have been installed downstream of a straight pipe of 70D. To further improve the flow conditions, a tube bundle flow straightener has been installed at the inlet of the straight pipe section. These tests are considered as reference tests, they have been performed both with and without flow conditioners upstream the meters.

2.3.2 Disturbed flow configurations

Only a limited number of flow disturbances had to be selected among the wide set of flow configurations likely to be encountered on gas networks. For this project, the meters have been installed downstream of two types of disturbances:

- **Single 90° bend**,
- **Double bend out of plane**,

The piping configuration upstream of the perturbations was a straight pipe of 62D.

In test phase one, the influence of these perturbations on ultrasonic meters has been examined without flow conditioners. In order to assess the influence of the upstream length required downstream the perturbations, the spacing between the outlet of the perturbation and the meter under test was: 12D, 20D and 30D.

In test phase two, the tests from phase one have been repeated with flow conditioners. For these tests, the spacing between the outlet of the perturbation and the inlet of the meter under test was 12D to be consistent with phase one. The distance between the flow conditioner and the meter was always 10D except for the tests involving the Daniel meter combined with the Profiler in order to respect scrupulously Daniel recommendations that stipulate 5D between the perturbation and the FC and 10D between the FC and the USM.

2.4 The test facilities and general test conditions

The whole series of tests has been performed on Bishop Auckland facilities with natural gas. The reference meters are turbine meters in DN100, DN150, DN200 and DN300, calibrated on pigsar™ facilities. The uncertainty of the Bishop Auckland facility varies between 0,19% for higher flow rates and 0,24% for lower flow rates. The Bishop Auckland facility is UKAS accredited.

The pressure level was 55bar. Each test was conducted at six flow rates between 5% and 100% of the maximum flow rate. This corresponds to mean flow velocities between 1,25m/s and 25m/s. Each single measurement point is determined as the mean of three acquisitions each lasting one hundred seconds.

3 RESULTS

3.1 Straight line tests

3.1.1 Straight line tests without flow conditioners

The results obtained on baseline without any flow conditioners are plotted on Fig. 1. These curves represent the deviation E_1 between the indications of the USMs under test and the corresponding indications of the reference meters, plotted versus average flow velocity. This deviation was calculated as follows:

$$E_1 = 100\% * \frac{Q_{USM} - Q_{ref}}{Q_{ref}} \tag{1}$$

with Q_{USM}: flow rate of the USM under test, Q_{ref} : flow rate of the reference meters. Both flow rates were based on conditions at the ultrasonic meter.

No adjustment has been performed after the straight line tests. It turned out that without any adjustment and correction the FMC meter and - to a lower extent - the Daniel meter underestimated the flow rate. These test results confirm that a primary calibration is required. It also can be pointed out that the curve shapes obtained with the three meters are relatively similar with a standard deviation of about 0,1%.

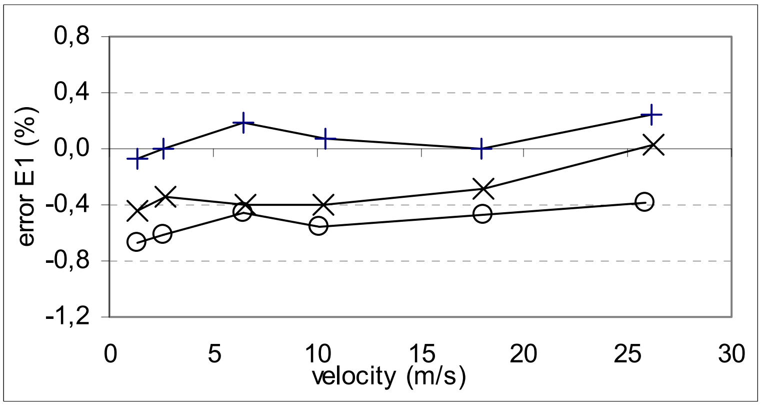


Fig. 1 - Deviation curves in straight line configuration without flow conditioners

X : Daniel Senior Sonic; O : FMC MPU 1200; + : Instromet Q.Sonic-4

3.1.2 Straight line tests with flow conditioners

Further tests under undisturbed conditions have been performed with the flow conditioners. The curves in Fig. 2 show the deviations E_C that represent the influence of the flow conditioner, i.e. E_C is the shift of the meter deviation due to the flow change induced by the flow conditioner, with regard to the cases without FC. No adjustments were made prior to these tests. E_C has been calculated as follows:

$$Ec = 100\% * \frac{Q_{USM} - Q_{ref}}{Q_{ref}} - E_1 \tag{2}$$

with Q_{USM}: flow rate of the USM under test with FC; E_1: deviation under straight line conditions, interpolated at the same reference flow rate. Ec would be the error curve of the meter if the meter had been adjusted using the straight line tests without flow conditioner as calibration curve.

The Daniel meter showed strong scatterings of the deviation curves at low flow rates. This is probably not solely related to the presence of the flow conditioners, as a matter of fact this behaviour was repeated in a large number of configurations with or without flow conditioners.

The FMC was not significantly influenced by the presence of the flow conditioners except for the highest flow velocity. This drift cannot be considered as a direct effect of the Gallagher flow conditioner. It has been found that this kind of drift occurred very often for this meter at high velocities, as will be discussed later the flow domain for this FMC meter should be restricted to velocities up to 20m/s.

The Gallagher flow conditioner induced a positive shift of the error curve of the Instromet meter, which seems to be sensitive to the specific distortion induced by this flow conditioner. However, the Instromet meter is not significantly affected by the flow modification generated by the other flow conditioners.

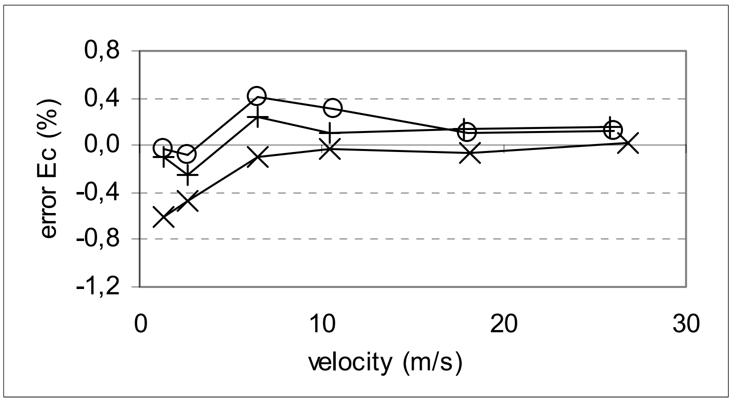
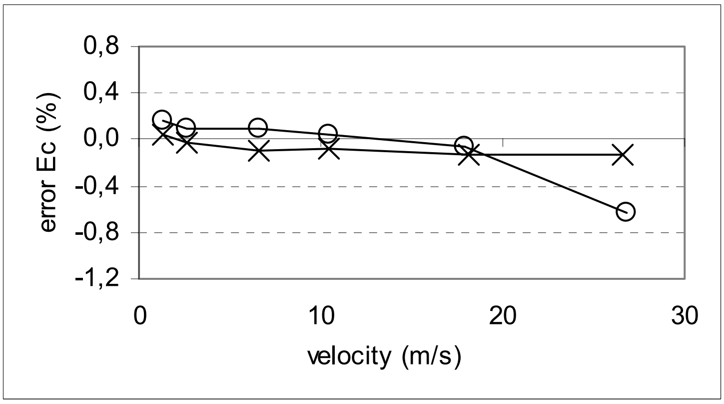
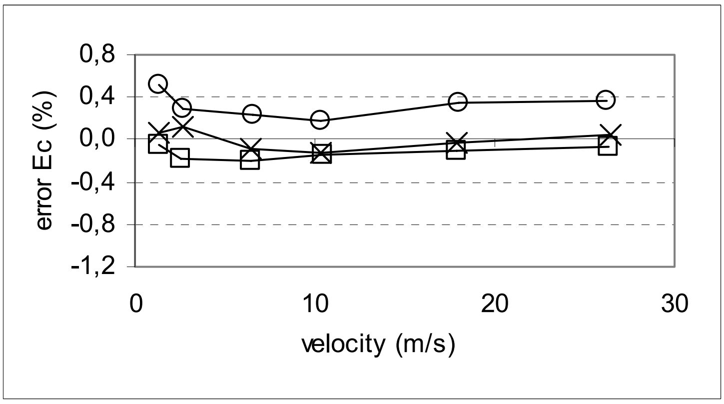
DANIEL	
FMC	
INSTROMET	

Fig. 2 - Shift of the meter deviation due to the flow change induced by the flow conditioner in straight line configuration

O *:* GFC; ***X*** *:* CPA; **+***:* Profiler; □: Instromet FS-3

From these plots it turned out that the modification of the flow profile induced by flow conditioners can affect a meter response even in fully developed flows. Each flow conditioner induces its own flow disturbance that should ideally remove any other upstream flow distortion. However, the additional deviations induced by the flow conditioners remain relatively moderate. These tests will be regarded as calibration curves of the packages “Flow conditioner + ultrasonic meter” in the following paragraphs. As discussed in paragraph 2.2, the major requirement for a flow conditioner is to generate a consistent flow pattern irrespective of upstream flow conditions. It seems that a length of 10 D between the FC used and the USMs is too short to generate a fully developed flow profile.

3.2 Disturbed configurations

The influence of the flow perturbations generated by single bend or double bends on meters readings are presented in the following paragraphs. The performances of the meters are assessed by considering the shifts induced by the perturbations relative to the straight line results.

For tests without flow conditioners, this shift is represented by E_C as defined in eq.2. Thus E_C is the shift of the meter deviation due to the flow changes induced by the perturbation, with regard to the straight line results without flow conditioners.

A similar definition was chosen for the analysis of the results obtained with flow conditioners: E_{CFC} is the shift of the meter deviation due to the flow change induced by the perturbation, with regard to the straight line results, but with flow conditioners.

$$E_{CFC} = 100\% * \frac{Q_{USM} - Q_{ref}}{Q_{ref}} - E_{FC} \qquad (3)$$

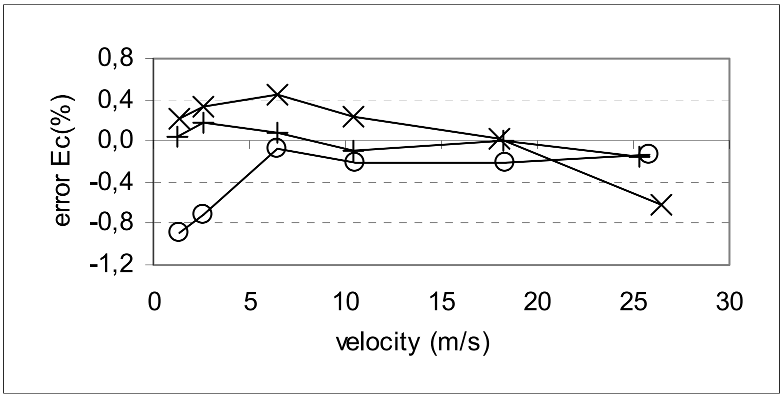
with Q_{USM}: flow rate of the USM under test with FC under perturbed flow conditions; E_{FC}: deviation under straight line conditions with FC, again interpolated at the same reference flow rate. E_{CFC} would be the error curve of the meter if the meter had been adjusted using the straight line tests with flow conditioner as calibration curve

3.2.1 Single bend without flow conditioners

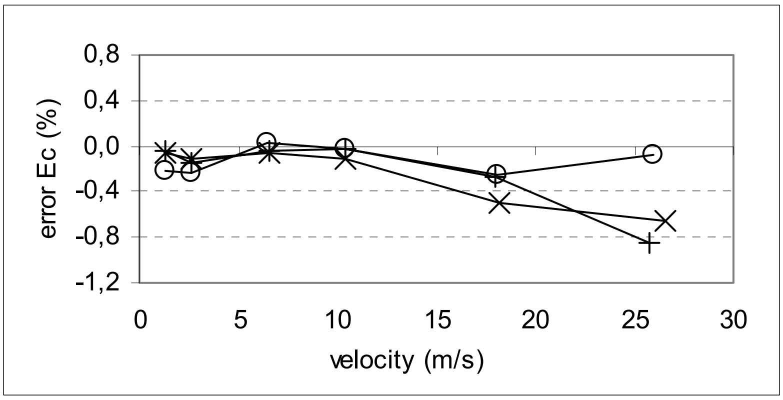
The results obtained downstream the single bend without flow conditioners are plotted in Fig. 3. The single bend induced some influences on the meters tested, for instance the quite large scattering of results of the Daniel meter at lower flow rates and the difficulties of the FMC meter to cope with the highest flow velocities. However, limiting the domain of the FMC to a maximum flow velocity of 20m/s, it can be concluded that the three meters correct quite well the perturbation generated by a single bend when installed 20D or 30D downstream the perturbation.

It has to be mentioned that the Instromet meter seems to be much more efficient with spacing of 20D and 30D. The meter reading is very linear all over the flow range for all distances. However, at 12D there is a more or less constant bias for this meter in the order of 0,4%. The spacing of 12D induced also some slight difficulties for the Daniel meter, which despite an acceptable flow weighted mean error (0,18%), showed very non linear results. The FMC manage quite well with the flow pattern 12D downstream the bend, but in a relatively limited flow rate domain.

DANIEL



FMC



INSTROMET

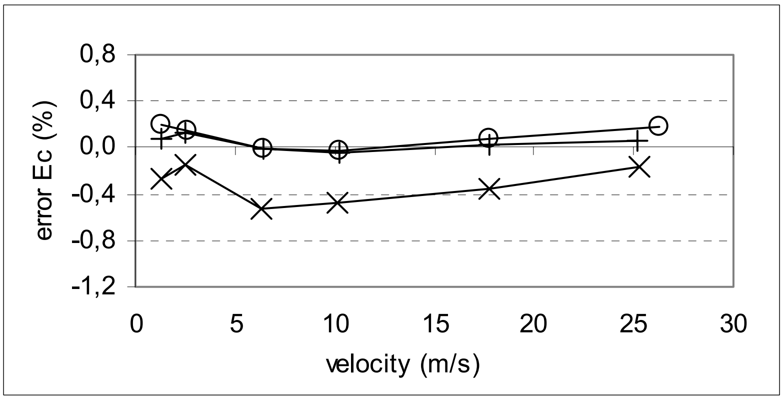


Fig. 3 - Shift of the meter deviation due to the flow change induced by the single bend

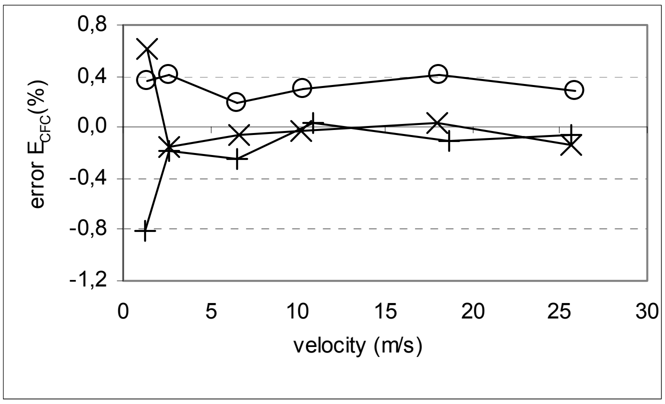
Spacing between the perturbation and the meter: ***X*** *:* 12D; ***O*** *:* 20D; **+** *:* 30D

3.2.2 Single bend with flow conditioners

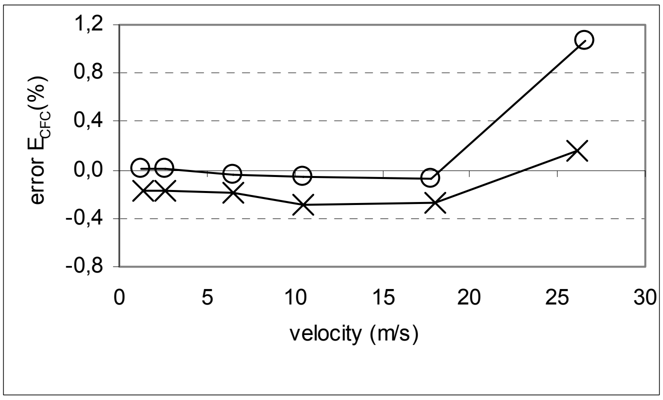
The results obtained downstream of the single bend with flow conditioners are plotted in Fig 4. The USM was installed 12D (15D for Daniel meter combined with the Profiler) downstream of the outlet of the perturbation. These plots present the shift E_{CFC} as defined in Eq. (3). It can be seen that flow conditioners improve the meter readings in the sense that the major shifts observed without flow conditioners are removed: The Daniel meter is quite linear except at very low flow rates and the bias of the Instromet meter is reduced.

The CPA is particularly efficient with Daniel and Instromet meters, while the GFC led to very satisfying results with FMC meter. However, from this remark it can be concluded that both do not generate exactly the same flow pattern when installed downstream a bend or a long straight line. The Profiler combined with the Daniel meter is quite well performing.

DANIEL



FMC



INSTROMET

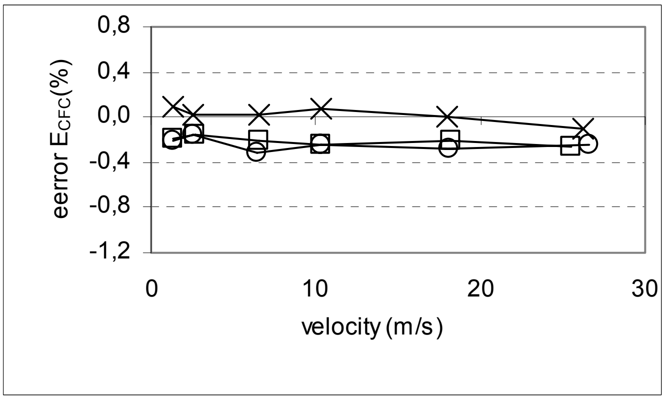


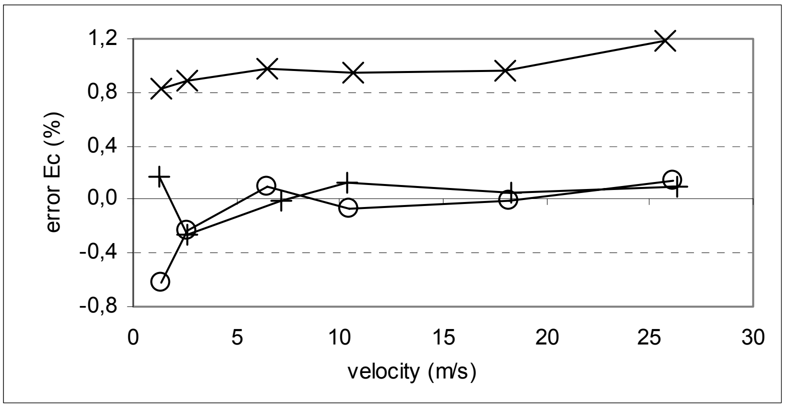
Fig. 4 -
Shift of the meter deviation due to the flow change induced by the single bend with regard to the straight line tests with FC

O** :* GFC; ***X** :* CPA; **+:* Profiler; □: Instromet FS-3

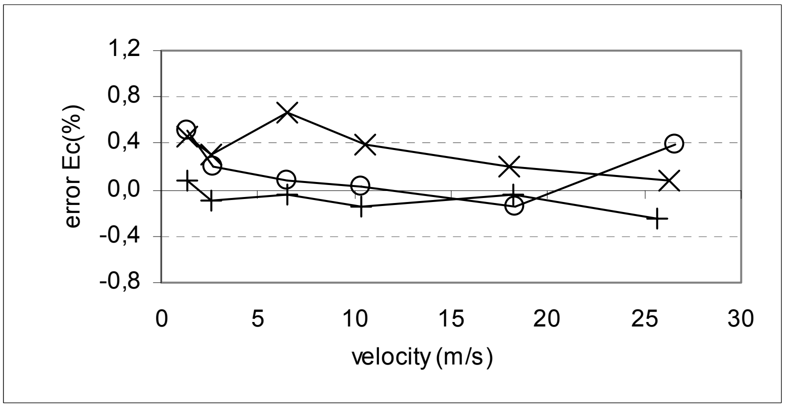
3.2.3 Double bend without flow conditioners

The performance of the meters 12D downstream of the double bends out of plane is not as good as the performance seen downstream of the single bend, see Fig. 5. In this case, the Daniel meter overestimated the flow rate in the order of 0.9%, while the Instromet meter underestimated the flow rate in the order of 0.4%. The flow weighted mean error obtained with the FMC meter is quite satisfying while the error curve is very non linear for the 12D position of this meter. Apart from low flow rates, the Daniel meter showed very satisfying results at 20D and 30D location. Again, larger deviations have been found with the FMC meter at high flow velocities with spacing of 20D and to a lower extent of 30D. For flow velocities lower than 20m/s; the FMC meter worked quite well despite an error of 0.5% at very low flow rate 20D downstream the disturbance. The Instromet meter showed deviations lower than 0.4% at 20D downstream of the perturbation and lower than 0.25% at 30D.

DANIEL



FMC



INSTROMET

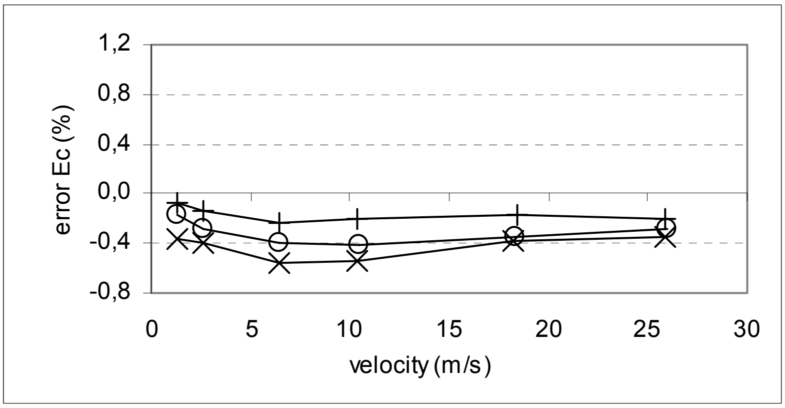


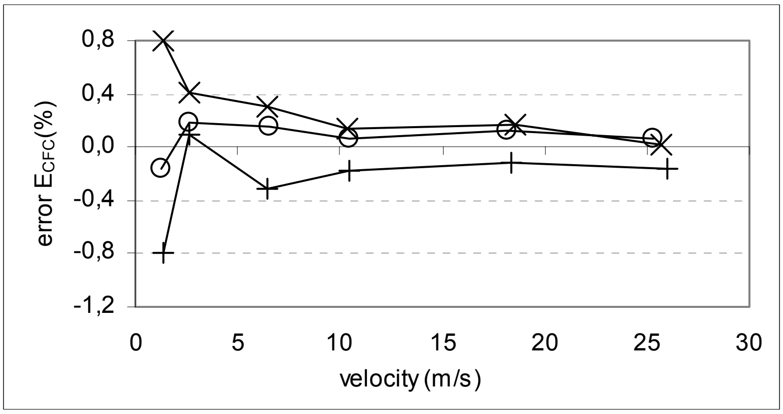
Fig. 5 - Shift of the meter deviation due to the flow change induced by the double bend

Spacing between the perturbation and the meter : *X* : 12D; *O* : 20D; + : 30D

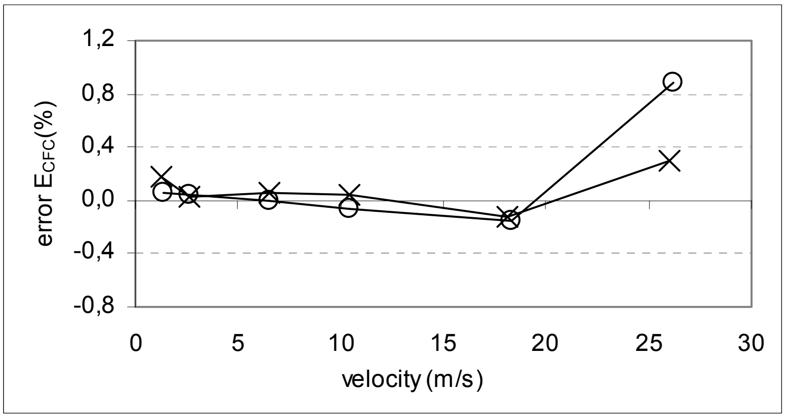
3.2.4 Double bend with flow conditioners

The results obtained downstream the double bends with flow conditioners are plotted in Fig. 6. These plots suggest that all the flow conditioners selected remove the main components of the flow perturbations, as a matter of fact the average error is significantly reduced and the error curve is flattened. Furthermore, the manufacturers recommendations led to satisfying results. GFC and CPA were very efficient when combined with the Daniel or FMC meters, while with the Instromet meter the most significant improvement was found with the Instromet FS-3.

DANIEL



FMC



INSTROMET

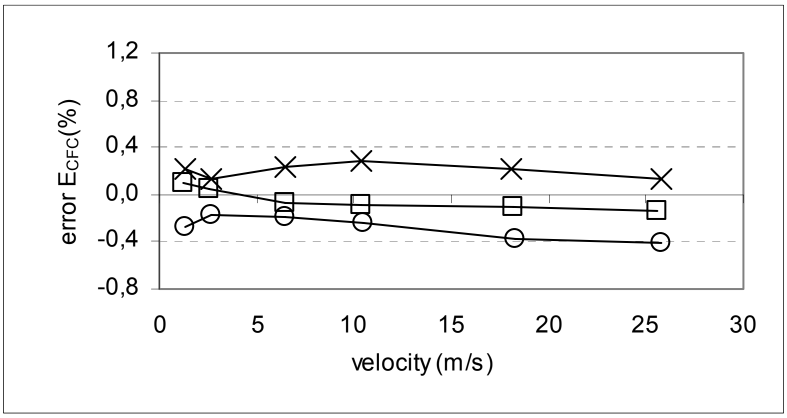


Fig. 6 - Shift of the meter deviation due to the flow change induced by the double bend with regard to the straight line tests with FC

O : GFC; *X :* CPA; +*:*Profiler; □ Instromet FS-3

4 Discussions

In order to sum-up the large amount of data gathered within this programme, the flow weighted mean errors (FWME) corresponding to the series of curves plotted in Fig. 1 to 6 have been calculated. As mentioned the FMC meter tested showed problems at higher flow rates in a large number of configurations. One conclusion of this work is that the flow domain for the FMC meter tested within this programme has to be restricted to a maximum flow velocity, which is between 20 m/s and 25 m/s. Nevertheless, up to this limit flow range very interesting results have been found with this meter. As a result, in this chapter the FWME have been calculated over a range of flow velocities limited to 20m/s to enable an appropriate comparison of the performances of the three meters.

It has also to be pointed out that in several configurations, the Daniel meter showed a large scattering of results at low velocities. However, this scattering is weighted and has only a limited influence on the value of the FWME and no further restriction have been applied to the flow range. In general, the Instromet meter showed a remarkable good linearity.

The calculations of the FWME have been performed over a range of flow velocities from 1,25 m/s to 20 m/s.

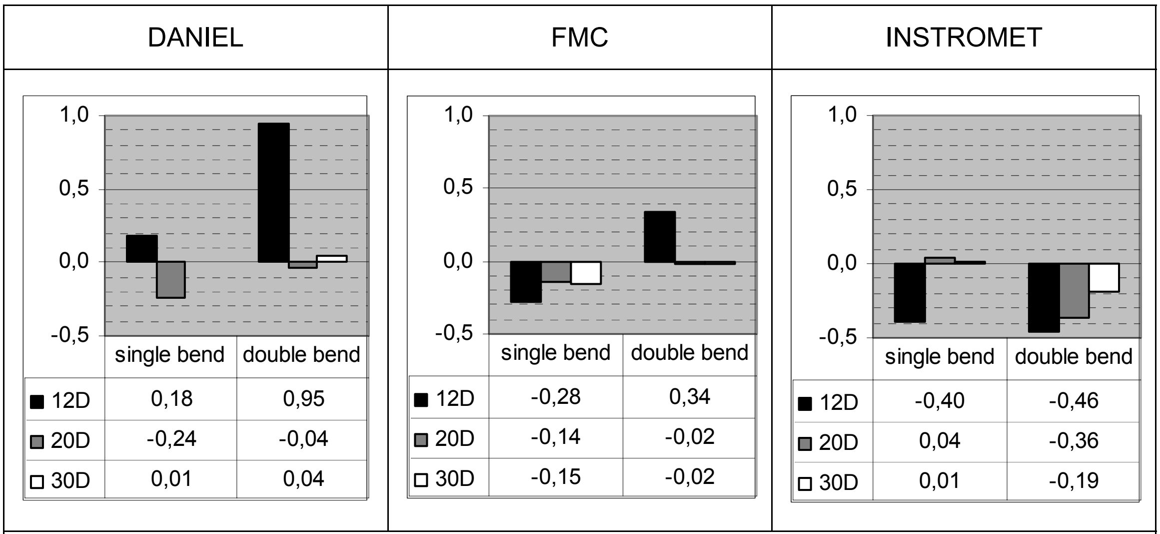
4.1 Influence of upstream disturbances on meters without flow conditioners

The results presented above showed that the ultrasonic meters tested within this programme remain sensitive to flow disturbances. Despite a large number of paths and sophisticated improvements, none of the meters is fully satisfying for fiscal gas metering when installed 12D downstream of double bends out of plane.

It also has been found that moving away the meter from the perturbation improves the meters responses. There is a single exception with the Daniel meter, which shows a slightly larger deviation at 20D compared to 12D for the single bend configuration, but this can be related to the difficulties of this meter to cope with low flow velocities (Fig. 3).

With regard to the criteria defined in AGA Report N°9, the results can be considered as satisfying, if the additional deviation induced by the flow perturbation is lower than 0,3%. The European standard for turbine meters (CEN 12261) gives a limit for 0,33% for the whole flow regime above Qt (=10% of Qmax for USM). If one applies these limits to the FWME it has been found that downstream of a single bend, a spacing of 12D between the bend and the meter is sufficient for Daniel and FMC, while the Instromet meter is only slightly out of these limits (Fig. 7). Nevertheless, the FWME is not a sufficient criterion and as shown on Fig. 3; the shape of the error curve is strongly non-linear for Daniel or FMC and despite attractive levels in FWME, 12D of straight line is too short downstream a single bend.

The perturbations induced by the double bends out of plane are more severe, so that the minimum lengths required to fulfil the 0,33% criterion on the FWME is 20D, observing that the Instromet meter is just out of the limit (0,36%). It has to be pointed out that respecting the condition of a straight pipe longer than 20D all meters can cope with the flow perturbations induced by a single or a double bend.



DANIEL

	single bend	double bend
12D	0,18	0,95
20D	-0,24	-0,04
30D	0,01	0,04

FMC

	single bend	double bend
12D	-0,28	0,34
20D	-0,14	-0,02
30D	-0,15	-0,02

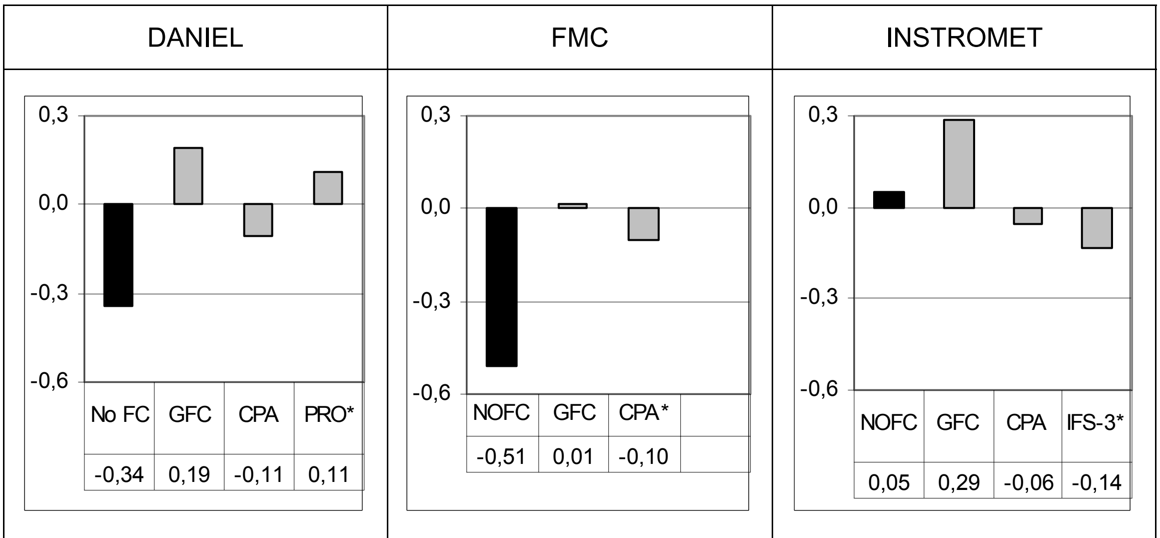
INSTROMET

	single bend	double bend
12D	-0,40	-0,46
20D	0,04	-0,36
30D	0,01	-0,19

Fig. 7 - FWME of Ec (eq.2) presented as curves in Fig. 3 (single bend) and 5 (double bend)
Tests without flow conditioners, all the values presented represent mean deviations from the straight line results

4.2 Effect of flow conditioners in straight line

The results presented above provide information about the minimum length required to install an ultrasonic meter downstream of flow perturbations. Downstream of more severe perturbations or in case of very compact installations, standards and manufacturers suggest the use of flow conditioners. The mean results of the analysis of the investigations with flow conditioners are summarized in Fig. 8. The FWME estimated on the basis of deviation E_1 (Eq. 1) for tests without FC and on the shift E_C (Eq. 2) for tests with FC, show, that downstream of the Gallagher FC and the Profiler the meters overestimate the flow rate whereas the CPA and Instromet FS-3 lead in the mean to lower indications. To summarize, the influences of all flow conditioners are within the 0.3% (0.33%) limit.



DANIEL

No FC	GFC	CPA	PRO*
-0,34	0,19	-0,11	0,11

FMC

NOFC	GFC	CPA*
-0,51	0,01	-0,10

INSTROMET

NOFC	GFC	CPA	IFS-3*
0,05	0,29	-0,06	-0,14

Fig. 8 - FWME of straight line tests: FC influence

■: FWME of E_1 (Eq.1), calculated relatively to the facility reference and presented as curves in Fig.1

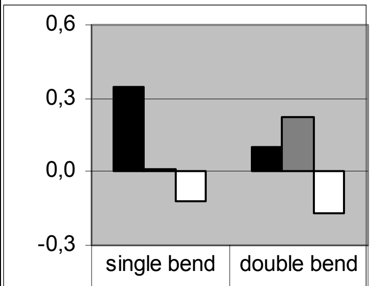
■ : FWME of E_C (Eq.2), the reference is the straight line test without flow conditioner and presented as curves in Fig.2

* : configuration recommended by the manufacturer

4.3 Influence of upstream disturbances on meters combined with flow conditioners

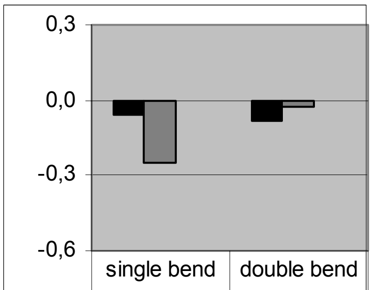
As the results obtained in this project show, the use of flow conditioners limit significantly the meters drift observed downstream the perturbations (see Fig. 9). As a matter of fact, all the results with flow conditioners meet the AGA 9 and CEN 12261 criteria; the Daniel meter combined with the GFC flow conditioner downstream a single bend just being on the limit. On the other hand, this flow conditioner led to very satisfying results with the FMC meter. The GFC induced a negative shift of the error curve of the Instromet meter in single and double bend configuration. The FWME obtained with the CPA are all below 0,25% with all the meters in single bend or double bend configuration. The recommendations of Daniel (Profiler), FMC (CPA) and Instromet (Instromet FS-3) lead to error levels lower than 0,25%.
The use of flow conditioners - previously calibrated with the USM – enabled the USMs, on the one hand, to reach satisfying results in terms of FWME, and on the other hand to flatten significantly the error curves.

DANIEL



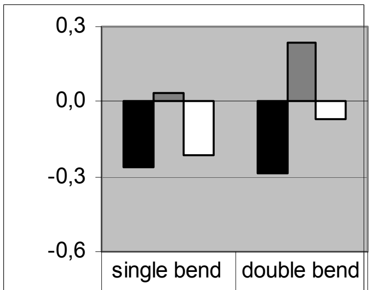
	single bend	double bend
GFC	0,35	0,10
CPA	0,01	0,22
PRO*	-0,12	-0,17

FMC



	single bend	double bend
GFC	-0,06	-0,08
CPA*	-0,25	-0,03

INSTROMET



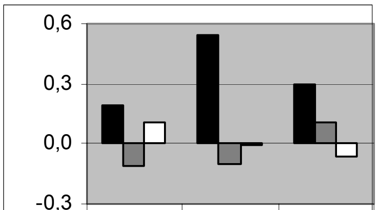
	single bend	double bend
GFC	-0,26	-0,29
CPA	0,03	0,23
IFS-3*	-0,21	-0,07

Fig. 9 - FWME of E_{CFC}(eq.3) and presented as curves in Fig. 4 (single bend) and 6 (double bend)
All the values presented account for a correction based on straight line results with FC
* : configuration recommended by the manufacturer

The previous results showed the ability of flow conditioners to reduce measurement deviation due to flow perturbations. From this point of view, the efficiency of the flow conditioner has been highlighted, but it requires a preliminary calibration of the complete package “FC – USM”. However, it can also be interesting to evaluate the FWME error relative to the straight pipe tests without flow conditioner to assess the possibility of combining a flow conditioner with an ultrasonic meter, which was calibrated without FC. This can also be regarded as an assessment of the meters ability to cope with another type of perturbation. These results are plotted in Fig. 10.

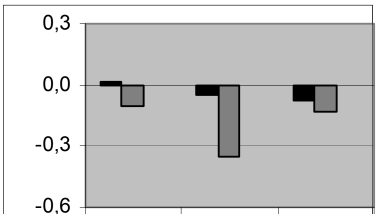
It could be concluded that some of the FC – USM combinations tested here do not require necessarily a calibration as one package, a calibration of the bare meter seems to be sufficient. This can be recommended only if the FC is efficient enough to remove the main components of the flow distortion in disturbed configuration and to induce limited perturbations in fully developed flow. Such combinations seem to be brought out from Fig. 10, but in general, to be fully efficient, it is still recommended to calibrate the FC with the USM.

DANIEL



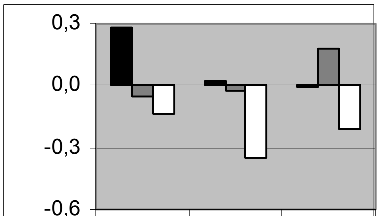
	straight line	single bend	double bend
■ GFC	0,19	0,54	0,30
▩ CPA	-0,11	-0,10	0,11
□ PRO*	0,11	-0,01	-0,06

FMC



	straight line	single bend	double bend
■ GFC	0,01	-0,05	-0,07
▩ CPA*	-0,10	-0,35	-0,13
□			

INSTROMET



	straight line	single bend	double bend
■ GFC	0,29	0,02	0,00
▩ CPA	-0,06	-0,02	0,18
□ IFS-3*	-0,14	-0,35	-0,21

Fig. 10 – FWME of Ec (Eq.2) downstream of perturbations,
all the values presented account for a correction based on straight line results without flow conditioner
* : configuration recommended by the manufacturer

5 Conclusions

The test results presented in this paper show that ultrasonic meters are still sensitive to flow perturbations. Despite using the most sophisticated techniques and algorithms of three market leaders, non-acceptable deviations due to flow perturbations are present, especially with short distance between the USM and the perturbation. Some sever conditions brought out deviations up to 1,2% and it has been found that the level in FWME can reach 0,9%. So, precautions are still required when installing an ultrasonic meter and several recommendations can be drawn from the data gathered within this project.

The measurement deviation induced by the flow perturbation decreases with longer spacing between the perturbation and the meter. This expected behaviour has been observed. From a more quantitative point of view, one has to recommend 20D undisturbed upstream pipe lengths for the use of ultrasonic meters without flow conditioners, irrespective of the meter type, in order not to exceed an additional deviation due to flow perturbations of 0,33%.

The use of flow conditioners clearly improved the metering behaviour, the FWME have been significantly lowered for all flow conditioners tested. Furthermore, the use of FCs flattened the error curves and the meters responses are more linear downstream the FCs tested. The meters with flow conditioners can be operated with 12D upstream pipe length with an acceptable additional uncertainty due to flow perturbations. Interestingly the results show that this behaviour can also be met for some combinations if the FC is not calibrated with the USM. However, it is still recommended to calibrate the whole package: FC – inlet pipe – USM. To summarize, these results confer to the meters tested a legitimacy regarding their use for custody transfer provided that the precautions in upstream length (20D) is respected or that a flow conditioner is combined with the meter.

The question whether these results are scaleable to other meter sizes is still under investigation within this GERG project. It has to be expected that the exact values as they are presented in this paper will certainly not be the same if other meter sizes are tested. It cannot even be stated whether the tendencies will be the same. The reason for this is the geometrical differences between different sizes of the same meter type.

REFERENCES

[1] T.A. GRIMLEY "12'' ultrasonic meter flow verification testing at the MRF", 4th Symposium on Fluid Flow Measurement Denver, USA June 1999

[2] www.Daniel.com

[3] www.instromet.com

[4] www.fmcmeasurementsolutions.com

[5] K. ZANKER, T. MOONEY. "The transit time ultrasonic multi-path gas meter – a reassessment" ", Proceedings of NSFMW 2003, November 2003 Tønsberg, Norway

[6] www.savantmsmt.com/GFC.html

[7] www.cpacl.com/products/flowc.htm

[8] K. ZANKER, D. GOODSON. "Qualification of a flow conditioning device according to the new API 14.3 procedure", Proceedings of FLOMEKO 2000, June 2000, Salvador Bahia Brasil

[9] K. COMMISSARIS, G. DE BOER "Realisation of compact metering runs with ultrasonic gas flowmeters and reducing measurement uncertainty", Proceedings of FLOMEKO 2003, May 2003 Groningen, The Netherlands