Volker Herrmann, Toralf Dietz, Andreas Ehrlich, SICK MAIHAK

Peter Stoll, Heiko Slawig, Verbundnetz Gas AG

The use of an Ultrasonic „Transfer reference meter“ to investigate differences of two gas meters in series in fiscal natural gas measurement.

Custody transfer meter station design often requires the use of two gas flow meters: The duty meter, and the reference meter. Both meters have to meet custody transfer requirements and therefore have a low measurement uncertainty. These type of installations ensure availability, redundancy and the on-line verification of the measurement.

The standard installation procedure for such meter stations includes a high-pressure calibration for both meters that normally should provide a “zero” difference between the readings. Even at proper station design in a few cases unacceptable deviations can be found directly after field installation of the meter. If there is not a simple reason, often the only appropriate measure is nowadays to check the high pressure calibration of the meters in an official laboratory. Even this extremely expensive and time consuming measure does not always guarantee success since possible installation effects will not be detected this way.

Another possibility is to define a “transfer reference meter package”, using one or two different state-of-the-art gas flow meters. A “transfer reference meter” is considered to be a calibrated meter with the highest achievable insensitivity to installation effects and long term stability.

This paper introduces the use of an Ultrasonic 8 path „Transfer reference meter“ and a reference meter of another technology to investigate differences as high as 0,8% in a German custody transfer station. This method can be used much more effectively since none of the meters under question needs to be taken out of operation or sent back. Additionally, using the more detailed profile information gained from an 8 path meter it is possible to investigate installation effects and detect sources of the deviations.

First results of the investigation of the above mentioned station will be shown and discussed. Possible ways of using transfer reference meters of different technologies and their advantages and drawbacks are also considered.

1 Introduction

VNG – Verbundnetz Gas AG – is the main company for gas transport in the eastern part of Germany. The share of natural gas transferred by VNG is 16% of the gas sales of Germany. The supply region is firmly integrated into the European interlinked system with 4 main delivery points. The natural gas network used for these tasks is composed of high-pressure pipelines having an overall length of about 7,100 kilometres. For supply purposes, VNG AG operates six underground gas reservoirs having a storage capacity of 2.2 billion m³.

As already mentioned, the natural gas is imported from the 4 large stations and delivered to the customers at about 300 transfer points. This explains the outstanding importance, from a metrological point of view, of the measuring technology used in the import stations.

Furthermore, the entire pipeline network is displayed in an online simulation by means of a so-called gas management system. In this context, a basic data supply as reliable as possible (exact quantity values) is also a mandatory requirement for achieving a stable model status. Here, the input measurements are of overriding importance due to their relatively small number.

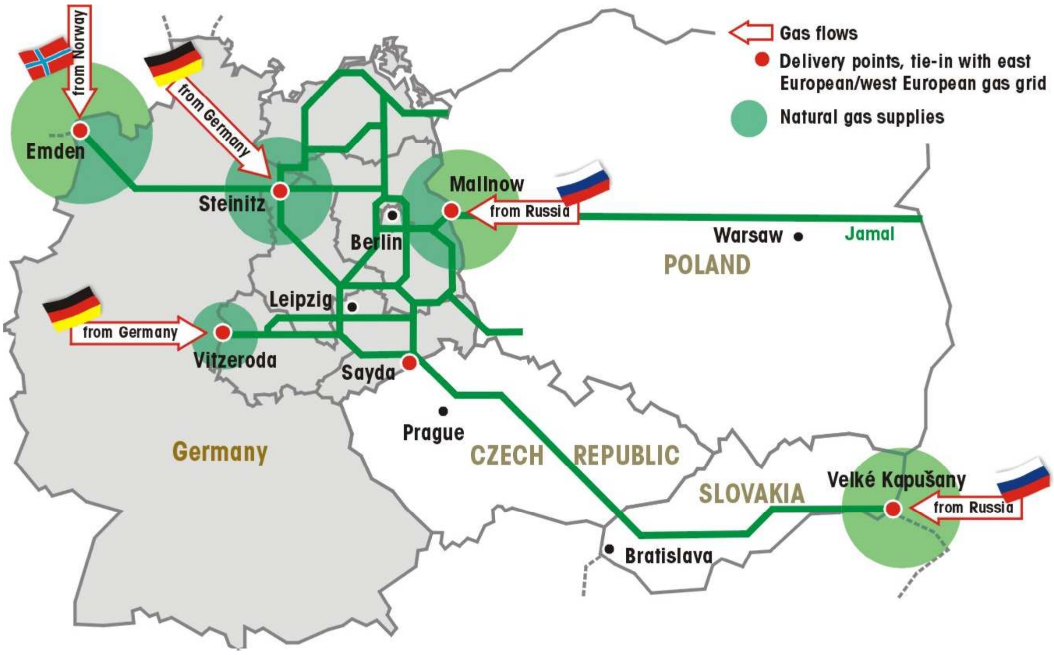


Figure 1 VNG main pipeline network

In Germany, two calibrated measuring devices are usually used in series in custody transfer stations. These devices mostly consist of a turbine gas flowmeter and a vortex flowmeter or increasingly a combination of turbine gas flowmeter and ultrasonic gas flowmeter. In this arrangement, only one meter designated as master meter is always used for invoicing. The second meter serves to detect systematic influences and should normally operate only with a small offset to the master meter. With purchase orders for measuring equipment in the recent past, VNG has been using the approach to define the deviation of the meters between each other not only during high-pressure calibration but also in the system-integrated state, taking a maximum permissible deviation of 0.5% as a basis.

In the present case, this value is not kept over the entire measuring range in a measuring installation. Deviations occur that represent either too large an offset or a non-linear behaviour of the meters. It is assumed that these are the result of system influences which affect the primary measurement, despite compliance with all statutory requirements.

In the previous course of diagnosing such deviations, it has turned out to be very difficult to detect the affected meter in measuring installations and - even more important - to convince the supplier of a possible malfunction, if applicable. Depending on the „know how“ or the willingness of individual firms, troubleshooting and fault detection thus develops into a very lengthy process in most cases.

To date, the next most obvious action in such a case was to retest the meters under high-pressure conditions at a test lab and to calibrate them again. Depending on the magnitude of the system influence, however, satisfactory results can be achieved only very rarely, in addition to the very high cost.

At this stage, the only remaining solution is:

1) to ignore the error, unless it is relevant with regard to invoicing, or
2) to apply other meter technologies at a high cost.

In this context, the logic is to use a kind of portable calibration package for natural gas for fault detection and/or fault assessment, similar to the approach with liquids, e.g. oil.

1.1 Approach to Problem Solution

The possible solution of the above-mentioned problems, presented here, is a **„reference meter section“** that is in this case installed instead of a control section downstream of the primary measurement.

The basic principle was the detection, or elimination, of possible system influences since in such a case no improvement of the measuring characteristics can be expected from the renewed high-pressure tests. With respect to possible system influences, special attention has been given to the flow pattern (asymmetry, swirl) and pulsations. Resulting from this information, a selection of the gas meter technologies to be applied was made.

Alternative variants, such as examinations of flow, pulsation and profile, do not constitute any alternative, neither in terms of time nor in terms of costs, except in simple cases.

As a result of the pro's and con's shown in table 1, the decision was made to use both the ultrasonic-type and the Coriolis gas flowmeter for the set-up of the portable reference meter section. During the first investigation phase, a turbine gas flowmeter was temporarily used as 3rd measuring system for referencing and plausibility analysis, of the results. This will not be required anymore in the final state of the reference meter section.

The reasons for the use of the ultrasonic gas flowmeter are primarily to be found in its well-known stability with undisturbed conditions, as compared to a turbine gas flowmeter, and in its outstanding diagnostic capabilities. Thus, the selected 8-path design allows a very specific statement as to swirl and flow pattern. Furthermore, it is now possible to compare the measured sound velocity of the ultrasonic gas flowmeter with those calculated from the gas composition, provided by a gas chromatograph.

A Coriolis meter was selected for the second measuring method. To date, only very limited experiences has been gained on its use in natural gas; however, this is acceptable within the scope of this investigation. This meter commends itself because of its also very compact fitted length and the expected accuracy.

	Overload withstand capability	**Flow pattern, swirl**	**Pulsation, mech. vibrations**	**Gas contami-nation**	**Remarks**
Orifice plate	😐	😐	☹	☹	long upstream length required, small measuring range
Vortex flowmeter	☺	☹	☹	😐	long upstream length required
Turbine gas meter	☹	😐	☹	😐	Established measuring system, multiple years of practical experience, extensively researched
Ultrasonic gas meter	☺	😐	☺	☺	4-path design can compen-sate for asymmetry and swirl, but only 8-path design allows quantitative diagnosis
Coriolis gas flow meter	☺	☺	☺	😐	abrasive influences of the gas flow, mechanical changes

Table 1 Technology overview and weighting from a user's point of view

The „reference meter section“ installed at VNG is shown below. All three meters mentioned above were installed at the mounting location in the position of a vortex flowmeter (Figure 2) belonging to a control section. The old control section was completely removed and replaced by the reference meter section (Figure 3).

Figure 2 Meter section with vortex flowmeter prior to modification

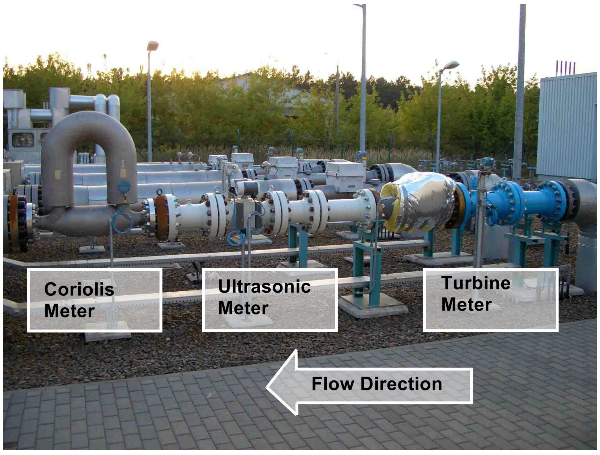


Figure 3 Installed reference meter section with Coriolis, ultrasonic and turbine gas meters (from left to right)

2 Technology and Calibration of the Reference Meters

2.1 8-Path Ultrasonic Flow Measuring System

2.1.1 Description

Standard components of the FLOWSIC 600 gas meter series were used for the 8-path ultrasonic measuring system. The arrangement of 4 additional measuring paths was in particular enabled by the meter body's symmetric construction, which was selected for the stability of the meter body geometry with respect to pressure and temperature (Figure 4). Miniaturised ultrasonic sensors ensure that the flow in the measuring section is influenced to a minimum extent only.

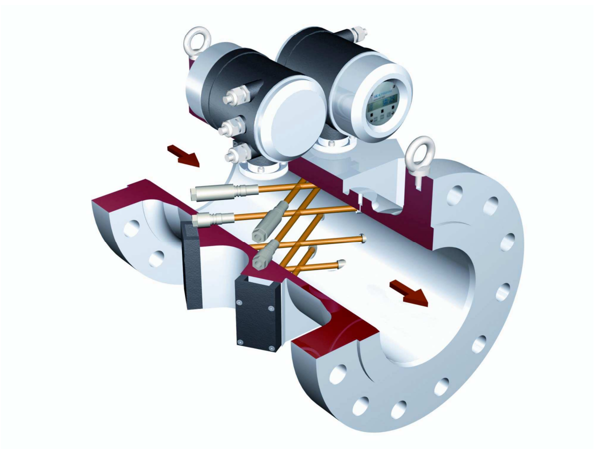


Figure 4 Arrangement of the 8 ultrasonic measuring paths

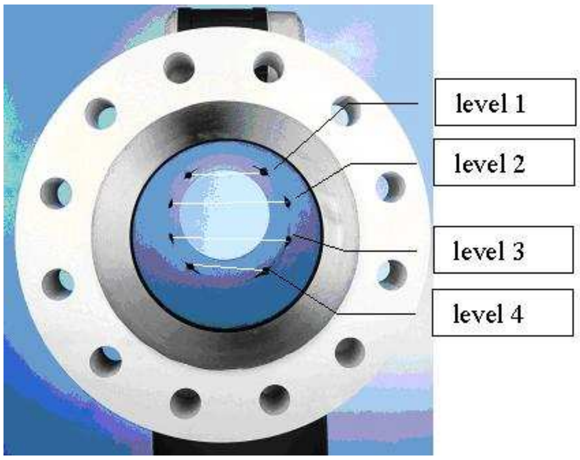


Figure 5 Distribution of measuring path levels over the cross section

The geometric position of the measuring path levels (Figure 5) has been maintained, exclusively to the FLOWSIC 600, since this layout provides a very good compensation for the flow pattern [1]. This completely symmetric 8-path arrangement creates 2 paths on exactly the same path level, and thus measurements are taken on the same level in the flow pattern. Due to the fact that the path angles are inverse to each other, tangential components are recorded with opposite sign. This enables a precise and transparent computation of these components. The additional measuring paths make it possible do show precise detailed information on local gas velocity components and to detect the possible causes of deviating measurements. As will be shown hereinafter, the FLOWSIC 600 may thus be calibrated on completely the same standard on air test stands under ambient conditions as well as under high-pressure conditions. The main focus within the scope of this paper, however, has been put on the use for diagnostic purposes.

The measuring result of an ultrasonic path is determined by the local velocity components in axial and tangential direction within the integration range of the ultrasonic signals. Figure 6 is supposed to serve for elucidation. The axial component, in the direction of the pipe axis, is the essential velocity component. Its value is determined by the gas transport. The tangential component is rectangular to the axial one. Tangential components represent swirl-subjected, rotating flows. This rotation is virtually always caused by the customary pipe fitting elements (double elbows out of plane, U-turns, T-fittings), but may be dampened effectively by suitable measures such as flow straighteners).

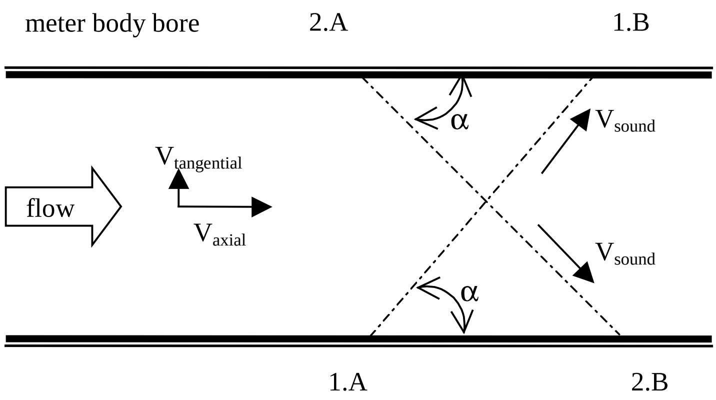


Figure 6 Schematic diagram

Referring to Figure 6, the following is to illustrate the influence of the tangential velocity component. The ultrasonic sensors of the system 1 (sensor 1.A and 1.B) are arranged at an angle α to the pipe axis. The distance between the sensor membranes defines the length of the measuring path (L_1). Accordingly, system 2 is characterised by the sensors 2.A and 2.B, angle α to the pipe axis, and the length of the measuring path L_2. As is well known, the transmitted signals propagate at the sound velocity of the medium. Taking account of the tangential velocity component, as shown in the figure, the signal transit time between the system 1 sensors is then defined by:

$$t_{1ab,1ba} = \frac{L_1}{v_{sound} \pm \cos(\alpha) \cdot (v_{axial} + v_{\mathrm{tangential}} \cdot \tan(\alpha))}$$

For system 2, comparable conditions are the result, only the sign of the tangential velocity component is changed. Consequently, the signal transit time for system 2 is defined by:

$$t_{2ab,\,2ba} = \frac{L_2}{v_{sound} \pm \cos(\alpha) \cdot (v_{axial} - v_{\mathrm{tangential}} \cdot \tan(\alpha))}$$

By calculating the signal transit time difference, it can then be demonstrated for the flow velocity of system 1 that the following is valid:

System 1	System 2
$v_1 \cong v_{axial} + v_{\mathrm{tangential}} \cdot \tan(\alpha)$	$v_2 \cong v_{axial} - v_{\mathrm{tangential}} \cdot \tan(\alpha)$

Taking the two independently computed gas velocities v_1 and v_2, it is now possible to state the amount of the axial and the tangential component:

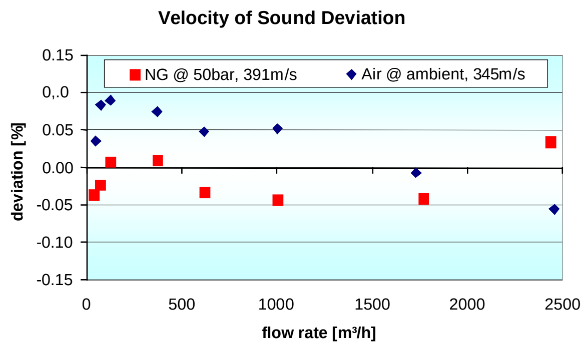
Axial velocity component	Tangential velocity component
$v_{axial} = \frac{v_1 + v_2}{2}$	$v_{\text{tangential}} = \cot(\alpha) \cdot \frac{v_1 - v_2}{2}$

When this logic is applied to all four measuring paths it is possible to demonstrate the asymmetry and swirl of the flow pattern and to use them for diagnostic purposes.

2.1.2 Calibration

In order to be able to use the reference meter section as universally as possible, it is particularly interesting to perform the calibration in a wide Reynolds' number range. This can be achieved when the flowmeter is calibrated both on a low-pressure test stand (air, ambient conditions) and a high-pressure test stand. If a relation of the low-pressure and high-pressure characteristic curves can be established, it will be possible to retest the reference meter section more cost-effectively in the future. The retest on a low-pressure test stand would then be sufficient to deduce the high-pressure characteristic curve.

For ensuring that only measurement errors allocated to the flow pattern are identified during flow calibration, the sound velocity has to be verified in advance. Only if the set geometric and time parameter values correspond to reality the measured sound velocity will be in line with the velocity computed theoretically. This would ensure independence from gas type and gas state (in this case air and natural gas). The determined deviations between the measured sound velocities, seen in relation to those computed theoretically from the gas analysis, are depicted in Figure 7 for the tested ultrasonic measuring system. The SonicWare® software was used to compute the theoretical sound velocity. The set of formulae has been standardised and documented in the A.G.A. Report No. 10.



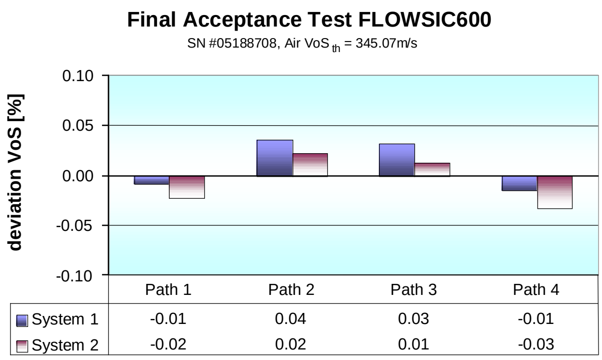
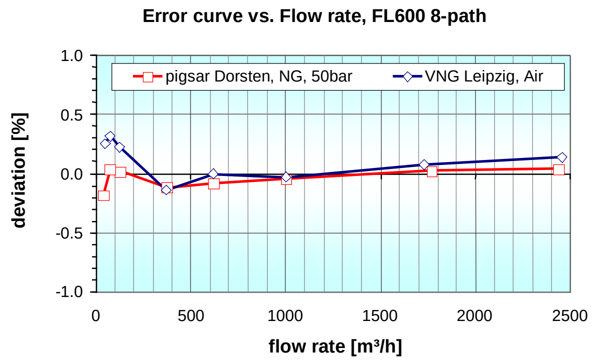


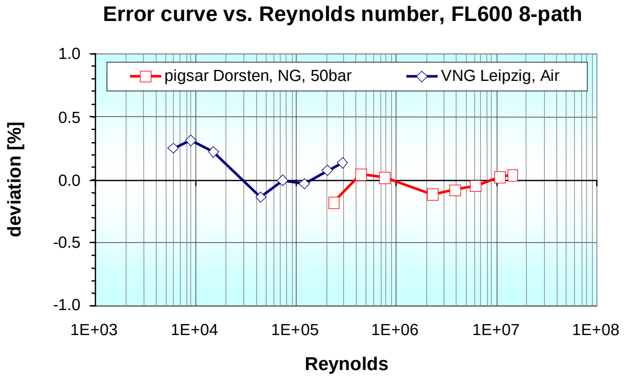
Figure 7 Illustration of the relative deviation of the measured sound velocity from that computed theoretically

Figure 8 Illustration of the relative deviation of the sound velocity measurement during final inspection prior to delivery

All determined deviations between the measured and the theoretically computed sound velocities are in a range of ±0.1%, at average sound velocities of 345m/s (air) and 391m/s (natural gas). Thus, the stability of the geometric and time parameters over a wide working range has been proven.

The flow calibration was performed on the recognised Pigsar® test stand in Dorsten for the high-pressure error curve for natural gas, and on the VNG-owned test stand in Leipzig for the error curve for air.





Figures 9, 10 Adjusted characteristic error curves of the 8-path ultrasonic measuring system, shown across flow rate and Reynolds' number range

The average deviation of –0.1% determined from the Pigsar® results was adjusted in both systems of the ultrasonic flowmeter. The adjusted results are shown in Figures 9 and 10, respectively. The conformance of the error curves is clearly below the specified test stand uncertainties of 0.16% for Pigsar® and 0.3% for VNG Leipzig. Figure 11 is supposed to elucidate this. The bi-variate point distribution shown is limited each time by the test stand uncertainties extended by the maximum linearity error of the ultrasonic flowmeter (0.2%). This results in a range of $\pm\sqrt{0.16\%^2 + 0.2\%^2} = \pm 0.26\%$ for Pigsar® and accordingly $\pm 0.36\%$ for Leipzig.

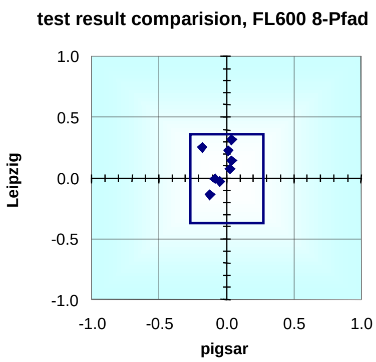


Figure 11 Comparison of high and low-pressure characteristic curves

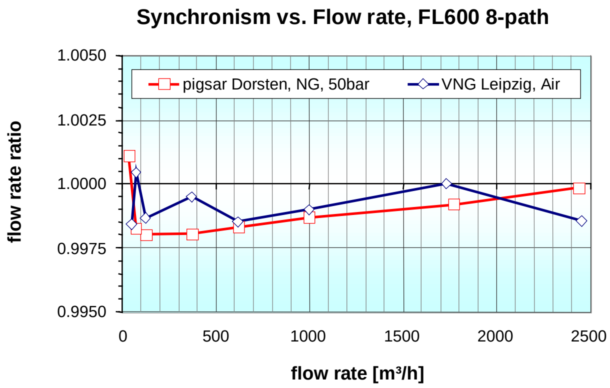


Figure 12 Synchronism of both systems during high and low-pressure test

2.2 Coriolis Gas Meter

Due to the experience already gained by the Emerson company in the field of gas measurement, a CMF400 of the Micro Motion Elite series was selected as the Coriolis gas meter. Its outstanding features are its compact construction, very good repeatability and the specifications that are very suitable for this type of application. The topics of zero drift, temperature and pressure sensitivity were intensively discussed in advance. The result of this discussion was that these influences could be excluded as not being relevant. Further information may be found in [3] and [6].

The meter used was repeatedly calibrated on a water test stand in Veenendall (uncertainty < 0.003%). Both tests performed produced an approximately identical result (<0.1%). The measuring range of 1:50 (Qmin/Qmax) required for the reference meter section has also been adhered to with an adequate uncertainty.

Micro Motion, Inc. Mass Flowmeter Calibration Certifica **414638**

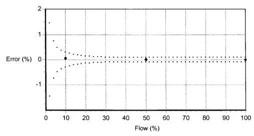
Product Code	Serial ID	Order ID	Line	Item	Customer Tag
CMF400M453NQFZEZZZ	414638				
2700R11DFZEZZZ	4002234				

CORE PROCESSOR SN:055-09430

Process

Process ID:2.17139540
Process Time:2005.07.14 14:49:21
Process Stand:32221 CMF300-600@SSCV
Stand Uncertainty:+/- 0.03%
Fluid:H20
100% Rate:140000 KG/HR
Pickoff:1
100% P/T:4.79 PSIG/26.7 C

Detail



Results

Status:PASS
D1:0
D2:1
K1:5771.654
K2:6964.938
DT:4.37
FD:608
DTG:0
DFQ1:0
DFQ2:0
FlowCal:4295.73.89
FFQ:0
FTG:0
DensCal:05772069654.37
FCF:4295.7
FT:3.89

Flow (%)	Nominal Flow Rate (kg/min)	Meter Total (kg)	Reference Total (kg)	Error (%)	Specification (±%)
100,0	2333,334	2638,254	2637,879	0,014	0,100
100,0	2333,334	2461,022	2460,9	0,005	0,100
100,0	2333,334	2395,152	2395,152	0,000	0,100
10,0	233,3334	2076,465	2075,411	0,051	0,292
10,0	233,3334	2064,479	2063,131	0,065	0,292
10,0	233,3334	2054,384	2053,118	0,062	0,292
50,0	1166,667	2230,473	2229,862	0,027	0,100
50,0	1166,667	2121,965	2121,644	0,015	0,100
50,0	1166,667	2233,117	2232,788	0,015	0,100
100,0	2333,334	2489,862	2489,673	0,008	0,100

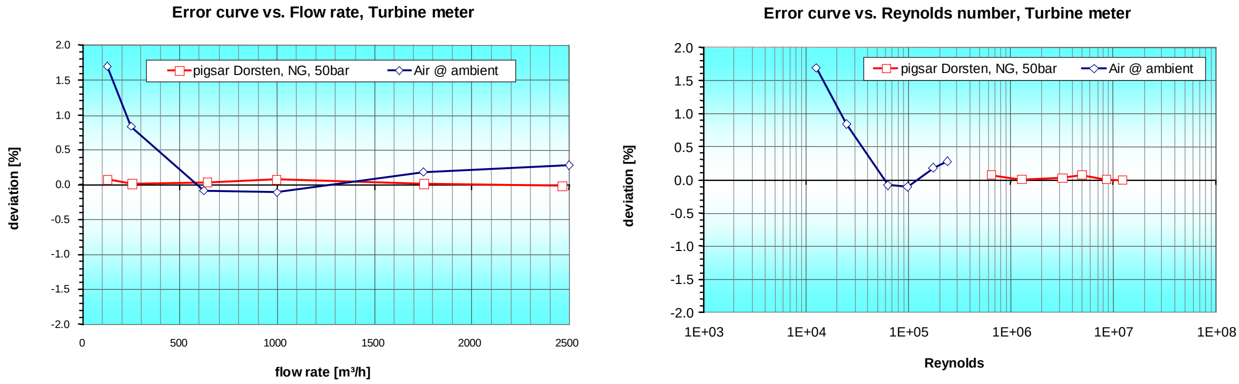
Figure 13 Water calibration, calibration certificate

At the time, no further high-pressure calibration with natural gas was carried out. The results seem to support the possibility of such an approach. In the later course of the series of measurements it is planned to verify the behaviour found in the 1st testing series both on a high-pressure test stand with natural gas and on an air test stand.

2.3 Turbine Gas Flowmeter

Since the turbine gas meter technology is well known, we have refrained from a detailed description within the scope of this paper. Detailed information on the turbine gas meter can be found in [4].

In our case, the description of the calibration results are of more interest. The turbine flowmeter also was tested both in air and under high-pressure condition. Again, the adjusted final result of the calibration is shown. The average deviation of 0.34% determined in the high-pressure test was adjusted by changing the pulse significance.



Figures 14, 15 Adjusted characteristic error curve of turbine gas flowmeter, shown across flow rate and Reynolds' number range

3 Signal Conditioning, Data Acquisition

Acquisition and conditioning of signals were done in different ways. First, each meter was equipped with its own flow computer ([5], Figure 16). Through the archiving function of these flow computers, the measured data is available for remote data readout. In order to have a basis of comparison for the meters to each other, all values were related to the converted volume at base conditions. For the ultrasonic meter and the turbine meter, the standard volume conversion is used, based on the gas state readings of a processed gas chromatograph (PGC). The PGC also provided the current value of the standard density required for the conversion of the mass information from the Coriolis gas meter. The station is equipped with 2 PGCs that showed only minimum deviations during the test period.

Figure 16 Quantity weight converter and measured value registration for the remote data inquiry of the reference meter section

In parallel with this, the measuring and diagnostic data was recorded and archived via the serial interfaces of the ultrasonic measuring system.

4 Results

In Germany, larger stations are generally split into a primary and a secondary section where the primary and secondary meters – as described in chapter 1 – must be within the deviation band defined by the operator. If there are deviations in the installation between primary and secondary meters, these can be diagnosed by means of the reference meter package described. The use of two additional independent measuring technologies allows conclusions to be drawn as to which of the installed meters is out of specification and thus a targeted and cost-effective improvement of the situation is made possible.

This approach has been implemented within the scope of this project. Since the data collected and conclusions drawn are not the sole property of VNG and SICK, they are not described here in detail. The installed reference meter section has clearly proven successful in the diagnosis of the deviations. The following will therefore address the technical observations that were obtained in the examination of the reference meter section while disregarding the primary section.

The main part of the measuring results shown herein was recorded in the months of August and September. A period of about 2 weeks was needed until commissioning was satisfactory. During this period, primarily first statements as to the zero point stability and the signal output of the Coriolis gas meter as well as to the synchronism and/or the signal processing of the two ultrasonic meter electronics were made.

At the beginning of the measurement, a clear diurnal variation of the meters between each other could be identified. The temperature, to be more precise, the not representative temperature measurement, very quickly turned out to be one of the greatest influencing factors. Among other things, for instance, the arrangement of the sensors between the turbine gas meter and the ultrasonic measuring system is not ideal. Even so, all these influencing variables allowed the measurements to work within the required ±0.5% range so that the actual measuring programme could be started.

4.1 Plausibility Check of Sound Velocity

After commissioning of the „reference meter section“, the measured velocity of sound was verified against the theoretical velocity of sound . On the first day , a provable difference between the velocities was established. A diurnal variation was also clearly identified in the difference. This variation correlated very well with the direct solar radiation on the reference meter section (Figure 17, 6th Sept. 2005). The protection of the temperature measuring location against direct solar radiation by an insulating mat produced a distinct improvement, although a diurnal variation in the measuring set-up is still visible (Figure 17, from 7th Sept. 2005 onwards). While there were deviations of up to –0.15% caused by diurnal variation, the small deviation of less than ±0.05% observed earlier on the test stands were also reached in the field operation after applying the insulation.

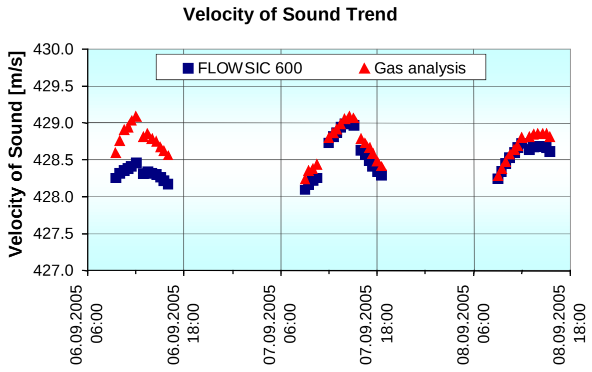


Figure 17 Comparison of measured to theoretical velocity of sound

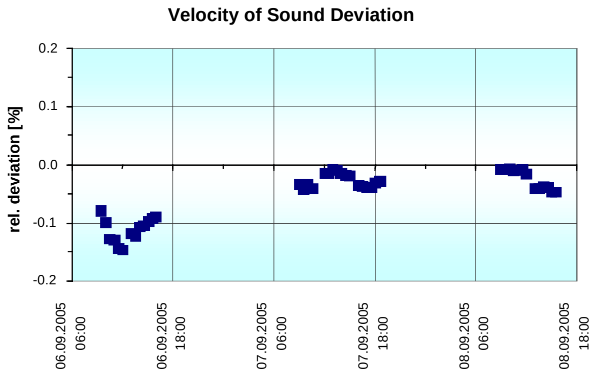


Figure 18 Relative deviation between measured to theoretically computed velocity of sound

4.2 Flow Pattern, Swirl

For an effective and fast assessment it is necessary to convert the offered, path-position-related detailed information on the axial and tangential velocity components into a dimensionless characteristic number. The swirl number K_v described in [2] is suitable for this purpose. Taking the numeric weighting of the path positions into account, the general swirl number definition specified herein can be modified for the ultrasonic meter as follows:

$$K_v = \frac{\sum_{i=1}^{4} w_i \cdot v_{axial_i} \cdot v_{\mathrm{tangential}_i}}{\left(\sum_{i=1}^{4} w_i \cdot v_{axial_i}\right)^2} \qquad w_i = \begin{cases} 0.1382 \text{ for } i = 1 \text{ and } 4 \\ 0.3618 \text{ for } i = 2 \text{ and } 3 \end{cases}$$

Amongst other things, the characteristic numbers specified in the table were determined in [2] by systematic velocity profile measurements using the laser doppler anemometry. These can be used to easily assess and classify the flow situation present.

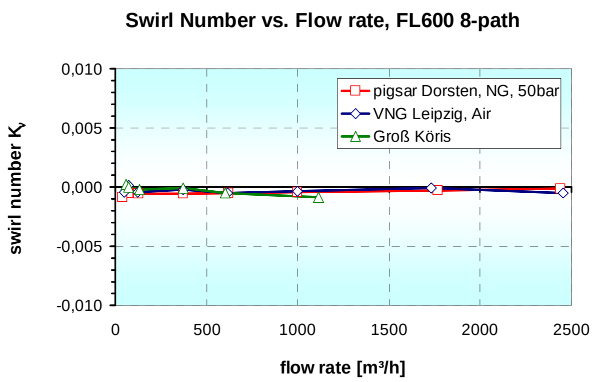


Figure 19 Illustration of determined swirl numbers

	Swirl no. K_v
Double Elbow out of Plane	0.092
OIML mild disturbance	0.115
OIML severe disturbance	0.181
T-fitting succeeded by 90°-elbow	0.134
Fully developed flow profile	0.00

Table 2 Characteristic swirl numbers for typical flow situations

From Figure 19 it can clearly be concluded that, on the test stands as well as in the installation, the swirl components are below those of disturbed flow situations by orders of magnitude. Virtually, a swirl-free flow can be assumed for the ultrasonic measuring system.

4.3 Comparison of Measuring Results

Figure 20 shows the results of the first endurance test phase for the ultrasonic measuring system and the Coriolis mass meter. Illustrated each time is the relative difference in the standard volume of the observed meter to the turbine gas meter, according to:

$$Dev = \left(\frac{V_{\text{meter}}}{V_{\text{turbine meter}}} - 1 \right) \cdot 100\%$$

Each point represented in the illustration corresponds to an acquisition time of one hour. The reduced number of measuring points for the Coriolis gas meter has its reason in the measuring programme. Due to the installation of the Coriolis meter directly upstream of further installation components, no measurements using the Coriolis meter were taken at high velocities. The turbine flowmeter will be removed after completion of this part of the programme, giving the necessary space between the Coriolis gas meter and the other installation components. The ultrasonic meter and the Coriolis meter will then be tested across the flow range that had previously been limited.

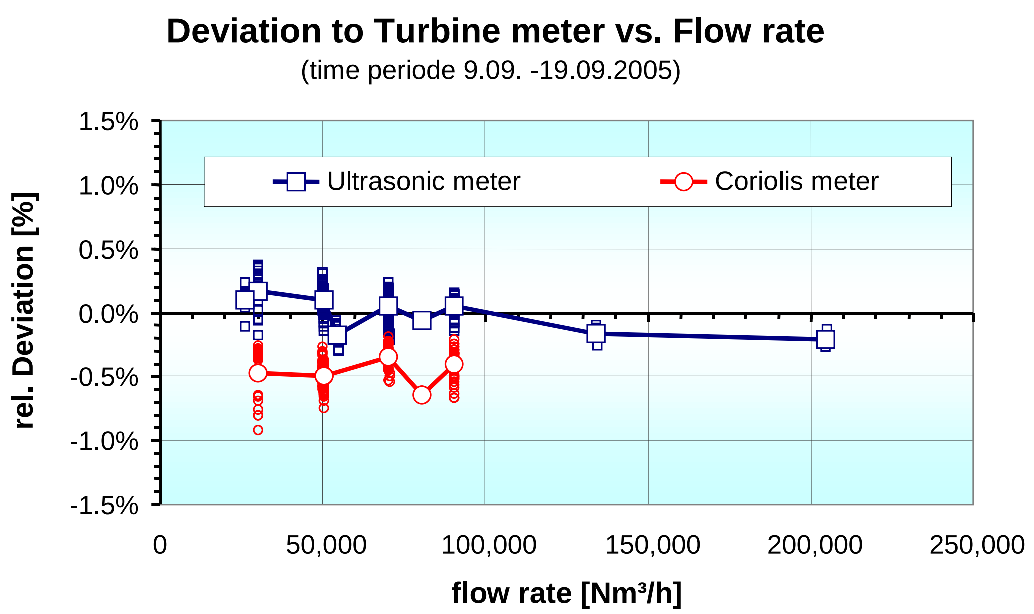


Figure 20 Relative deviations of ultrasonic and Coriolis gas meter to turbine gas meter

Taking account of the uncertainty still present at the current stage with respect to the representative temperature measurement , the following statements can be made:

1. Ultrasonic and turbine gas meter show the characteristic error curve determined during the joint calibration. The average deviations to each other are in the range of ±0.2%.
2. First of all, a stable offset of –0.5% to the turbine and ultrasonic gas meter must be stated for the Coriolis flowmeter. In this context, it should be mentioned again at this point that this meter, as a mass meter, was calibrated with water only. An offset correction was intentionally not made since the question of which meter has to be corrected in which way can not be answered at present. A remedy would be the calibration of the Coriolis meter on a high pressure or low pressure test stand for natural gas. The clarification of the offset will form part of the further programme. A retest on the SICK-MAIHAK air test stand in Dresden is planned at least for the reference meter section of ultrasonic and Coriolis flowmeters. There, the spatial and metrological conditions are available in order to test the entire reference meter section.

In summary it can be said that the target requirements were complied with and „almost better“ than expected performance by the reference meter section under adverse metrological conditions were achieved. All people involved assume that this meter section at this operating site may be used to 100% as a reference for other measurements!

As mentioned before, the crucial influence on the stability of the reference meter section is exercised by the temperature. Even with a temporary solution using makeshift insulation, the influence of temperature is still recognisable. This means that all meters, together with their inlet lines, will have to be insulated when this reference meter section is to be used for outdoor measurement. Moreover, the temperature measurement will have to be arranged close to the relevant meter.

Using the diagnostic data from the ultrasonic gas meter, statements as to the flow and profile behaviour within the reference meter section could be made and verified using appropriate evaluation methods. It has thus become possible to assess or evaluate system influences that cannot be recorded during a high-pressure test, directly in the installation.

Due to the unique situation of being able to examine three meters, which are based physically on most different principles, simultaneously in one meter section, a great deal of data has been recorded, archived, and evaluated. Of course, a final evaluation without further work is not feasible at present, as constantly new considerations also keep on raising new questions. With the time frame available, it was unfortunately not yet possible to answer all identified questions. These would be, for example:

- Cause of the stable offset between ultrasonic/turbine gas meter and Coriolis gas meter
- Optimal arrangement of the temperature measuring points and reducing the influence caused by the difference between gas temperature (about 22 °C) and fluctuating ambient temperature
- Diagnostic opportunities through „acoustic“ temperature computation based on the measured sound velocities (temperature layering of the gas)
- Proof of system influences (none were identified in this case) or detection of normally ignored influences
- Which accuracy or reproducibility is attainable in the future, taking account of the aspects of long-term stability and portability of the reference meter section?
- Development of new re-calibration concepts for high-pressure natural gas facilities

On the part of VNG it can be stated that during the tests series no restrictions whatsoever as to the Coriolis gas meter were recognisable. This means for the future that the permanent series connection of ultrasonic and Coriolis meters will be an absolutely conceivable measuring approach, particularly for bi-directional measurements.

5 Conclusion / Outlook

The use of a reference meter section integrating different measuring technologies for diagnosing installation-conditional deviations under operational conditions has proven to be very successful. The combination of metrological experience of the manufacturers, the application-engineering competence of the operator, and the utilisation of the diagnostic capabilities of state-of-the-art measuring methods, such as the ultrasonic and the Coriolis measuring technique, allows an in depth study of the behaviour of the measuring section. Taking this as a basis, it is possible to optimise station layouts, reduce the cost for additional high-pressure calibrations, and ensure reliable operation.

The plan for the future is to examine the offset between ultrasonic/turbine gas meter and Coriolis gas meter by extended tests. Among other things, the entire package will be tested once again both under high-pressure and low-pressure conditions. At the same time, a statement will be made as to the long-term behaviour of the relative deviations.

As an additional intellectual approach, the idea has arisen to examine whether a sole low-pressure calibration and/or water calibration for meters may be sufficient in the future.

6 Literature

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