# Test Benches for Calibrating Custody Transfer Gas Meter

Several transmission and distribution companies in Western Europe operate test facilities for testing industrial meters like larger diaphragm gas meters, rotary gas meters and turbine gas meters. Alternatively, they lease mobile provers. Those installations are not suitable to perform the initial calibration (and try to save money on the calibration costs), but are suitable to perform all kind of tests in order to improve the integral quality of their metering system and to optimize the operations by means of advanced (statistical oriented) maintenance programs.

Remarkable is that outside Western Europe the implementation of a Test facility as an integral part of the operations is often disregarded, although the gas meters and related metering systems must be considered as the (only) moneymaker/cash register of the gas utility. The necessity to control the quality of the meters on a permanent base seems evident.

Presented herewith are just a few reasons, based on considerations of Western European Gas companies, to start with in-house testing, calibration and recalibrations. The risk and consequences of not implementing adequate test programs will be discussed and illustrated with some examples. Attention will be given to advanced service/maintenance programs as well as the problems that will arise during implementation when essential meter data (history) does not exist.

Just to get an idea on the economic value involved in distribution and transportation two examples are presented below:

**GFO Rotor meter**

With an average load of 25% a G100 (160 m3/h) @ 4 bar registers in 16 years:

**28.032.000 $Nm^3$**

With an Nm3 price of 20 dollar cent this equals an economical value of 5.600.000 dollar

**<u>GFO Turbine meter</u>**


With an average load of 25% a G650 (1000 m3/h) @ 8 bar registers in 10 years:

**284.700.000 $Nm^3$**

With an Nm3 price of 20 dollar cent this equals an economical value of 56.000.000 dollar

Only after a proper calibration, these meters can become cash registers. Without calibration they operate similar to slot-machines, one easily can lose several percentages (%) in accurate measurement

Mistreatment during transport

Statistics have shown that most of the meter failures are caused due to meter mistreatment during transportation and installation of the meter and during starting up. With all due respect for the technicians in the field, their understanding for the equipment and its sensitivity is not always sufficient. Training programs will help to improve the skill of the technicians and thus the quality of the metering systems. However, to train people effectively there must be an overview of the shortcomings. A reporting system of meter mistreatment and failures must be set up first. Since the results of a trainings program becomes effective after the training, the question is what went wrong before! This is a serious question since the commercial and financial consequences are rather large.

Figure 1: Damaged Ball Bearings of a G650 Turbine Gas Meter caused by a Shock during Transportation**.**

For example a turbine meter (G650 running at 4 bar natural gas) has dropped off the truck during transportation to the site. The inertia of the turbine wheel created such an impact on the main bearings that the balls and the raceway of the outer and inner bearing ring were damaged before the turbine wheel had ever turned. Since the damage was not visible at the time of installation, the meter was not exchanged for another one. Even with this initial damage, the meter has been in service for more than 3 years before the high frequency pick-up showed problems due to a complete bearing failure (figure 1). The meter has been repaired and is in service again.

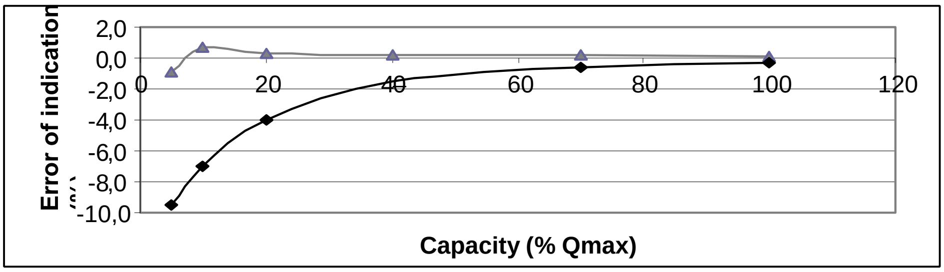


Figure 2: Error shift of a turbine meter after three years in operation with damaged bearing.

As part of a R&D project the meter was tested before repair. The results of the original error curve and the error curve after 3 years in operation with damaged bearings is showed in figure 2. An estimation is made what the initial damage has cost the gas company in monetary terms. Other and in addition to the actual repair costs, which

are negligible in respect to the loss of gas, the estimated costs (loss of income) are about 60.000 USD. As shown in the calculation below.

Average hourly consumption (25% load):1000 * 0,25 * 5 Bara = 1250 Nm3/h
Average yearly consumption:10.000.000 Nm3/a
Average consumption in 3 years :30.000.000 Nm3
Assuming an average under reading of 2% :600.000 Nm3
**Loss of income (1 Nm3 = 0,2 USD) :120.000 USD**

Fortunately the subjected meter failed after three years of operation due to instability of the high frequency pick-up. Still a lot of gas companies rely purely and entirely on the skills of the technicians in the field and the national legislation defining time frames between two (re)-calibrations (5, 8, 12 or even 16 years!).

After this event, the subjected gas company started a training program for the field technicians to emphasize the value of a proper meter treatment and started testing meters on a regular base, disregarding the national legislation.

*With sample testing of meters being a standard part of the maintenance procedures, structural problems can be recognized in earlier stages. Corrective measures can save a lot of money and contribute to advanced service maintenance systems.*

## Cutting cost without losing control

One must recognize that the nature of the gas business is changing rapidly and drastically due to deregulation and Third Party Access (TPA). The purpose of open access (TPA), as a consequence of the deregulation of the gas market, is to maximize the value of the pipeline capacity and to create competition. Both to encourage increased efficiency to provide the customers with lower priced gas.

Where open access is in place, the end user now can negotiate the purchase of large quantity of gas from the producer, or from a gas marketer or broker who in turn has agreed to purchase larger quantities of gas from the producer. The broker lines up customers in competition with the established Gas Company. The pipeline company and /or distribution company between the gas producer and the gas user**,** now becomes a transportation company transporting gas being owned by other parties. The only income distribution companies have is a transportation fee paid to them for transporting the gas. It is obvious, therefore, that the measurement of the gas, both into the pipeline and out of the pipeline at customer’s location must be as accurate as possible.

In the meantime the manufacturer of measurement equipment, the users and the authorities got the messages. The equipment itself, the requirements of the user and the legislation have changed in the past years to meet the demands related to the new gas market.

As a drawback of the fear for competition and the never ending drive to increase efficiency to survive, especially distribution companies try to cut cost everywhere within the company**,** not always realizing that this will affect the quality of the operation. Especially the handling, servicing and maintenance of measurement equipment are frequently disregarded, which is in conflict with the necessity to increase the level of measurement accuracy. Often companies decide to leave the metering equipment in operation as long as the local authorities allow, not realizing that a degradation of the equipment due to a less effective maintenance program means that the amount of unregistered gas will increase, causing considerable financial losses. One must realize that reducing the maintenance in general, for instance the filtration equipment, will have an impact on the quality of the gas meters as well.

This is the opposite way of thinking in respect to the transmission companies, who are investing more and more in statistical analysis of metering equipment in operation, increasing the recalibration frequencies and installing redundancy to avoid under readings at all time.

Cutting cost in operations in general and in maintenance in particular can be achieved in a sufficient way without losing control. But this takes time and requires a different approach. Ways to reduce operational and maintenance costs are changing away from a time-based maintenance/servicing program to a system where all the maintenance is done based on events or on predictions (preventive maintenance). In both systems the efficiency is increased since the maintenance/service is only carried out when necessary. In case of preventive maintenance also the required capacity (service/maintenance technicians) is minimized since the day-to-day work can be predicted and scheduled. Both the event oriented system as well as the preventive system will be more efficient than the old fashioned time related systems. For safety equipment, pressure regulators and filtration equipment, several gas companies in Europe already implement these new systems.

The power of these new systems is that historical data is used to judge the consequences of a registered event and to define the adequate action to be taken. For instance, if the pressure drop over the in- and outlet of a rotary meter changes significantly, it could mean that the main bearings of the meter are in a bad shape. Revision seems to be necessary to avoid losing larger quantities of gas.

*To make a proper judgement**,** the relation between the increased pressure drop and the degradation of the performance must be known.*

For preventive maintenance systems historical data (statistics) is even more essential, since these systems will predict - just in time - maintenance based on trends (monitoring changes). In the case of the rotary meter, the increase of pressure drop over a certain period can be used to calculate, in an economical sense, the time frame in which the meter has to be pulled-out for a revision.

*A gas meter test facility will be an indispensable tool to build up databases needed to define relations between the performance of the meters in operation and the monitored trends.*


## Quality control: increasing performance

Metering equipment dropping off from trucks is just a unique example, since most of the technicians recognize the possible damage and the consequences there off. However one cannot expect that people not familiar with metering equipment will have the same responsibility. After the meter has been calibrated in the factory and the final inspection has been carried out**,** the control of the meter is in the hands of shipping agents. It is a utopia to believe that they always will treat the meter as it should be. The agent probably does not even know that he is shipping a highly advanced and accurate metering device. Even if the shipping agent has responsible truck drivers reporting irregularities during the transportation, the bumpy roads and other transport related shocks are still not taken into account. To avoid even the smallest risk, large gas companies like Gasunie in the Netherlands, require transportation with special trucks equipped with high class shock absorbers and use shock indicators mounted to the meter. This applies for transportation over a maximum of 200 km using roads of a high quality.

Although GFO Europe is taking special care for the packing of their meters, there is always a risk of exceeding the limits. The Risk of transportation damage is rather small, but the consequences are large and comparable to the earlier mentioned case with the G650 turbine meter. For that reason many companies do perform a check-on-arrival on the meters before sending them to their final destination. A rather simple but widely used test is the so-called spin-time test. Speeding up the wheel and checking the time until the wheel stops rotating. For highly advanced and accurate meters this method has become too inaccurate. The spin time method gives only a rough indication, unable to detect the smaller defects that cause a steady wear process in terms of time.

The smaller – dangerous – defects can only be recognized by performing an accuracy test. Even the smallest defects of the meter will generate a shift in respect to the original test results as performed at the manufacturer's premises.

*With traceable and accurate test facilities even the smallest defects can be detected.*

Another dangerous drawback of the deregulated market is the tendency to purchase gas meter equipment using tender procedures (ICB-International Competitive Bidding). Purchasing through tenders looks to be an efficient way to reduce the investments to enhance the company's profitability and thus to satisfy the shareholders. But this way of modern business is a risky way since it will put the price pressure on the manufactures and will in most cases lead to quality reductions to be able to manage the costs. Buyers not having a decent check-on-arrival control have to face the risk that the products purchased do not meet the specification.

*Only the threat of having a* check-on-arrival *control system by means of a traceable test facility will per definition increase the quality of the products.*

The incoming control mechanism and results can only be considered as an instantaneous photo. Reducing production cost of metering equipment can also be achieved by using less suitable and qualified materials. Materials that will differ from the original products that have been subjected to duration test as part of the type approval procedure/program. On the long run this can affect the performance of the equipment possible ending in losses of income due to under reading. Anyhow, the use of degraded equipment looks to be in conflict with the company objective to cut cost on service and maintenance. Especially tender wise purchased products must be monitored excessively (sample testing) during the first years of operation. Earlier mentioned relations between the long-term performance and the typical local conditions (including the skills of the technicians and the bumpy roads) must be reviewed.

*Test facilities are of great value in performing duration tests (in laboratory or on site) with unknown or modified gas metering equipment.*

## Accreditation as a marketing tool

Quality Assurance programs and the certification becomes very important in trading and selling gas. A direct comparison can be made with GFO Europe as a seller and manufacturer of gas meters. To sell our product we need to be ISO 9000 certified. Without an ISO 9001 certification GFO Europe would not sell anything. For gas companies the situation will be similar in the near future. Instead of the sales of gas meters like GFO Europe, gas companies do sell gas as a product, which means the gas companies have to face ISO9000 certification as well to stay within the gas business. If not forced by a governmental act and/or legislation, it will be required by the customers. Gas companies can use the ISO9000 certificate as a marketing tool that will help them to survive in the marketing field of open and strong competition.

Part of the ISO certification will be the quality control of the used metering equipment. The ISO9951 requires that the uncertainties of the used equipment must be within certain levels. To meet these levels**,** not only the use of accurate equipment is required, but also the long term stability (drift) has to be taken into account. To estimate the long term stability or drift, excessive testing has to be carried out. This will be the only acceptable proof. Without proof**,** the figures for the long term drift as used in the uncertainty calculation will be fairly high, resulting in a higher frequency of re-calibration.

*Being certified gives the gas company the opportunity to operate a test facility for legal calibrations and recalibrations (accreditation). The accreditation can be considered as a powerful marketing tool.*

Increasing gas prices, as to be expected in the next decennia, will make customers nervous. The number of complaints about the accuracy of the gas meter will increase.

Having accreditation will open the possibility to clarify disputes on a cost effective but neutral bases.

Higher gas prices or economical depressions will also make customers very creative and innovative in trying to tamper the gas meter. In the larger Dutch Cities there are magazines showing how to manipulate the reading of the meter. The city of Amsterdam estimated that 5 – 10% of the gas meters (mainly domestic meters) are tampered! A few documented tricks resulting in a rather large under reading are for instance:

- Injecting grease into the main ball bearings.
- Damaging the gears in the index by means of a magnifying-glass (is hardly visible on the outside).

*With a low pressure test facility, tampering of a gas meter can be proved beyond doubt. Having a test facility and an adequate anti-tampering program will reduce the number of attempts.*

## Local (national) legislation and directives.

In a deregulated market with open access, there is a strong need for legislation to avoid discussions between the partners. Discussions not only about the contracts but also about the equipment to be used. For instance, about the accuracy class, the turn down ratio, the effects of the gas density, the effects of perturbations, the effects of intermittent flow, the effects of pulsations, etc. National or international legislation and directives, defining minimum requirements and test procedures will certainly contribute and avoiding disputes.

*Setting up directives and legislations is only possible when the equipment for proving and testing according to these legislations and directives is available.*

## Upgrades at local repair shop.

Well-designed gas meters have proven to be accurate for 10 years and longer when treated according to the manufacturer's transportation/installation instructions (operations manual). However, with a rapidly and drastically changing gas business due to deregulations and third party access, the required functionality of the gas meters is changing as well. As an example, the remote reading of gas meters to meet the future demands of third party access (TPA). In a TPA environment the financial transactions occur much more often and unpredictable due to short time contracts. To read the gas meters at any time remote, the tendency in Europe is to use encoders. Encoders convert the actual reading shown by the mechanical index in to a digital format. This new technology will get a worldwide acceptance in a few years. Most of this new electronics are imbedded in the gas meter index. To implement this new technology the metrological seals have to be removed with conventional gas meters. Breaking the metrological seals means that the meter is no longer approved for custody transfer, and has to be returned to the manufacturer. Most of the smaller modifications, like upgrading the index with encoder technology, can be carried out locally in a reasonable equipped repair shop. To prove that the modification has been carried out within the tolerances set by the manufacturer a calibration/recalibration has to be carried out to get the legal status again (metrological seal).
Another technology coming up, is the use of integrated optimized thermo wells. As has been proven in recent research projects, the tube based thermo wells cause significant offset in the temperature reading in the connected volume corrector. Especially at lower gas pressures – up to 5 bar – the heat conversion from to gas flow to the thermo well is poor compared to the energy flow from the meter body into the tube.

As a result, the measured temperature in the thermo well can differ a few degrees from the actual gas temperature. Since three degrees offset equals 1% error of reading, this systematical over or under reading gets more and more attention.
This problem can easily be solved by using integrated and isolated thermo wells with cooling ribs to enlarge the contact area with the gas. However, installing those optimized thermo wells can mean that the meters needs to be verified again.

*With a low pressure test facility legal metrological prove can be given after locally implementing upgrades to the gas meter.*

## Design and construction of test facilities

Verifying or calibrating gas flow meters becomes more and more a necessity as explained before. Up to a few years ago buying and maintaining a test bench was restricted to larger gas companies due to the investments and costs involved. Besides this, the need for operating a test bench was not given, since the gas price was rather low.
As per today, test benches are available on the market within the financial reach of even the smallest gas companies due to improvements in the field of master meters and applied electronics. However, not all the available technique is suitable for calibrating all commonly used gas flow meters. Although certified by recognized institutes – most of the time expressed in a superb uncertainty level like better than 0,3% for just the used reference meters (masters) -, it will not automatically mean that these masters installed in the bench will give adequate results. As an example, a pulsating rotary meter will create resonance in the tubing of the facility and as such will cause significant errors during the test. Another potential error source is the effect of line pack at low capacities. NMi has recognized these short comings and express the uncertainty of the test bench as CMC (Calibration and Measurement Capability) based on calculation given by the "guide to the expression of uncertainty in measurement". Also the meters under test can degrade the performance, as is known for testing rotary meter without sufficient damping of the pulsation. In the uncertainty calculations used by the NMi (expressed as CMC), many uncertainty sources are quantified, like:

- Repeatability of the meter under test
- Uncertainty resulting from calibration of the Temperature, sensors, pressure sensors, barometer and the primary reference meter
- Uncertainty in temperature, pressure and deviation reading due to the approximation by a polynomial
- Fluctuating pressure and temperature at the reference points of the primary and secondary reference meter
- Inadequate measurement of the temperature due to temperature gradients in the test facility (line pack)
- Uncertainties associated with leak flow rate
- Trends in performance, occurring during the life-time of the facility and the used components
- Clock pulses are truncated due to the "A gated by B" method

To get an approval for a test bench, all these sources will be quantified resulting in a CMC for the bench. The given CMC is of course a snap shot, meaning that the CMC is only valid for a certain time frame. After a few years (depending of the load of the bench), the facility has to be maintained under supervision of the authorities i.e. the proper functioning and the traceability to recognized standards has to be proven. This maintenance exercises are very expensive, but a newly developed program called “remote verification of test benches” reduces these maintenance costs to an acceptable level. To use this remote verification/validation, the test facility must be designed in a different way. All master meters must be double for cross reference checking, and a set of transfer meters is part of the facility. No need to explain that the procedures for maintaining the facility must be adopted in the quality assurance system of the user.

Even with the most accurate test facility, the meter under test will remain the most unpredictable factor. For this reason, the construction of the bench becomes essential. As an example the testing of a rotary meter will be explained.

## Testing rotary meters at low pressure

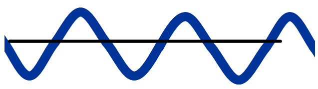

Figure 3: Rotor meter introducing pulsations

A rotary meter is a positive displacement instrument, discrete volumes are transported from one side of the instrument to the other. The releasing volumes will introduce ripples in the flow.

Because of these ripples special precautions have to be taken to do a proper calibration on air.

These ripples can cause unwanted resonances during calibration, resulting in unrealistic results. The German DVGW did a “round robin” intercomparison between several test benches using a standard production rotary meter. The results next page show clearly the effect of the pulsations on different types of test benches.

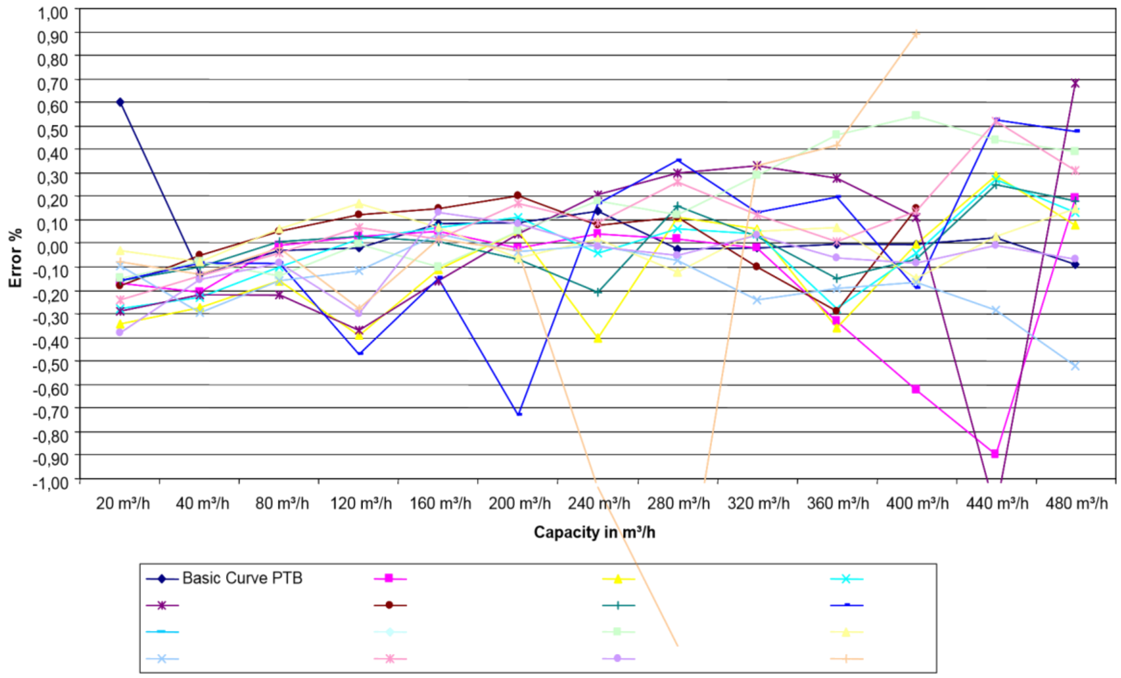


Figure 4: Pulsation effect on different types of test benches

Several installation-flow combinations result in unpredictable `spikes`. In such a point the meter is resonating, meaning that there is a longitudinal wave interfering with the dynamics of the meter and the gas flow passing the meter.

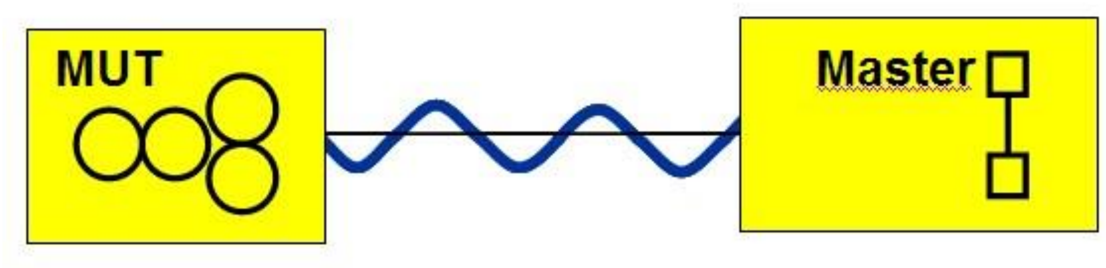


Figure 5: pulsations will effect turbine master meters

After experimental research done by some European manufactures, the phenomenon of resonance can be reduced to a non-significant level, by damping the ripples out using a vessel with absorption material. The dimensions of the vessels and the used damping material are critical in order to reduce the resonance of the full flow range of the meter under test and the bench itself. Besides the dampers, the interconnecting piping between the meter under test and the bench are specially designed for the testing of rotary meters. For instance, it is not recommended to use the in- and outlet section of turbine meters for rotary meters since this will generate resonances and as a results error shifts up to 1%. Another mistake made rather often, is the use of turbine masters for testing rotary meters. Research done in the 80$^{th}$, has shown that turbine meters will drift significantly by intermittent flow. Due to the inertia of the turbine wheel, the wheel cannot follow fast flow changes. As the pulsation of the rotary meter (meter under test / MUT) is fast and severe, a turbine meter as master meter is basically not allowed. The same applies for testing turbine meters (Meter under test) with rotary meters as master. The turbine meter under test will have an over reading due to the pulsation of the mater rotary meters. The most commonly used solution to overcome all these problems is to use pulsation free rotary meter (Twins, with double set of impellers phase-shifted) as masters and sufficient damping of the pulsation caused by the meter under test


Figure 6: pulsations should be isolated by damping device

As testing gas flow meters under atmospheric conditions with air becomes affordable by new techniques, the question arises whether testing with air under atmospheric conditions give sufficient results for meters to be used under higher natural gas conditions. The answer is clearly no. The air atmospheric testing is basically a low cost substitute only suitable for meters operated with natural gas at pressures (densities) up to 4 bar. Both turbine and rotary meters to a lesser extent, will perform different when used at natural gas at higher densities. Essential differences between air and natural gas are the viscosity of the medium and the density. Taken into account that the commercial value of meters used under high pressure conditions is must higher than those used under low pressure conditions (pressure factor multiplier) , it is strongly recommend to test or calibrate the subjected meters as close as possible to the actual operating conditions (i.e. similar density, viscosity and Reynolds number). The recently released European directive for gas meters will only allow meters calibrated close to operating conditions for billing purposes. Also the latest AGA7 and the OIML137, emphasize the use of calibrations close to operating conditions. The fact that these two directives still leave the decision open to the user is more or less forced by a practical problem. The global capacity of all certified test facilities will not cover the need and the growth of certified facilities is slowed down since suitable location are not so easy to find.

As a consequence, - hardly a substitute for high pressure natural gas - test benches operated with compressed air are used for calibrations. Those test benches use compressed air in a loop configuration. Since compressed air differs from high pressure natural gas on all crucial aspects like density and Reynolds number, the results are rather doubtful especially when turbine meters are calibrated that are effected by density and Reynolds number. The use of compressed air will not give the user the guarantee that under actual operating conditions the meter performs as shown during calibration. Besides the use of compressed air, the calibration can be carried out with $CO_2$ as medium. This technique, developed by Terasen Gas Company, now called Fortis BC (Vancouver, Canada), has proven that all the drawbacks of using air are eliminated. The use of compressed $CO_2$, can be considered as a reliable substitute for high pressure natural gas, which becomes evident realizing that by testing the meters at about half the actual operating pressure, the key parameters like density and Reynolds number become similar. The $CO_2$ technique is already approved by many institutes worldwide (NMi, Measurement Canada, SWRI, etc.).

## Calibration at actual operating conditions

Up to now the story on "low pressure testing" has been covered. With current gas prices and applications upto 8 bar low pressure calibration seems to be an acceptable balance between costs on calibration and risks by misreading. The European Directive EN12261 even requires that meters used at pressure above 4 bar have to be calibrated at conditions as close as possible to the operating conditions.

For high pressure applications several other calibration methods are in use. Main reason for testing at high pressures is that low pressure results cannot simply be extrapolated to higher pressures because they could result in unacceptable misreading's. In the below picture the typical behavior of a non-optimized turbine meter is given, the behavior at high pressure is totally out of range.

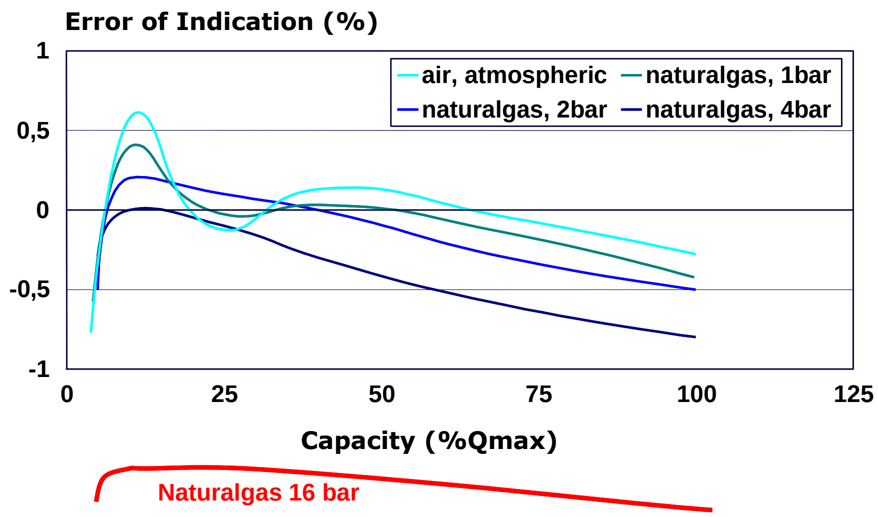


Figure 7: Non optimized turbine meter at high pressure

Calibration at conditions as close as possible to the operating conditions makes sense since the density and as thus the Re-numbers can affect the accuracy of the meter.

The low pressure data simply does not contain enough information to make a reliable prediction for an errorcurve at high pressure. Low pressure results are typically dominated by bearing friction, and laminar-turbulent transitions. At higer flowrates density, and viscosity, so-called Reynolds start playing a major roll. Only tests performed close to operating condition will result in reliable results, explicitly stated in:

EN12261 text

For a meter type specified for measurement in a pressure range below or equal to 4 bar the error of indication test shall be carried out with a gas at atmospheric conditions (± 100 mbar).

For a meter type specified for measurement in a pressure range extended above 4 bar the error of indication test shall be carried out with a gas in the range of the specified metering conditions. The tests shall be carried out at least at the lowest and the highest working pressure specified by the manufacturer. However, for specified maximum pressures above 50 bar a test at 50 bar is deemed acceptable.

AGA 7 text

**6.3.1 Calibration Conditions**

Research (Reference 3) has shown that the performance of turbine meters varies with changes in flowrate and operating pressure. These variations are related to changes in Reynolds number, and in some cases density, and are particularly significant at low and intermediate operating pressures and flowrates. Attention to these issues at the time of calibration is crucial for optimal measurement. The following sections provide further guidance in this regard.

## Predicting performance at high-pressure conditions.

Gas meters used under high pressure conditions are often calibrated under these conditions. The European Directive EN12261 even requires that meters used at pressure above 4 bar have to be calibrated at conditions as close as possible to the operating conditions. Only a few laboratories are available for these testing with natural gas at high pressure. The most commonly used facilities are listed below:

| Name /Location | Country | Authority | Pressure Range (bara) |
|---|---|---|---|
| Utrecht | Netherlands | NMi | 9 |
| Bergum | Netherlands | NMi | 9 – 50 |
| Westerbork | Netherlands | Gasunie and NMi | 60 |
| Pigsar, Dorsten | Germany | Ruhrgas and PTB | 14 – 50 |
| TCC, Winnipeg | Canada | TCC and NMi | 65 |

Table 1: Recognized High Pressure Test Laboratories.

Although some other High pressure facilities are under development, the total number is limited, causing delays up to months. Most of the test laboratories are centralized in Western-Europe meaning that transportation over quite a distance is necessary (check on arrival testing!). For meters up to flange rating ANSI300 (maximum operating pressure 50 bar) even all the facilities available are located in the Netherlands or in Germany.

Calibration at conditions as close as possible to the operating conditions make sense since the density and the Re-numbers (including viscosity) can affect the accuracy of the meter.

For the recalibration of high pressure meters the approach can be more economical. When the initial calibration is carried out with low pressure air and high pressure natural gas, the relation between the low pressure and the high pressure characteristics is known. It is proven that when the low pressure characteristics after being in operation are not changed significantly, the high pressure characteristics have not changed too. This means that by a comparison between the original low pressure results (blue print) and the results of a low pressure re-calibration, the characteristics under high pressure conditions can be predicted. Especially when the required accuracy levels are within +/- 1% this method will be satisfactory and is economical very attractive by saving an expensive high pressure calibration.

The average prices levels expressed in USD for high pressure calibrations are listed in table 2.

| Size (inches) | ANSI 150 | ANSI 300 | ANSI 600 |
|---|---|---|---|
| 2 | 1.000 | 1.750 | 1.750 (50 bar max.) |
| 3 | 1.000 | 1.750 | 1.750 (50 bar max.) |
| 4 | 1.000 | 1.750 | 1.750 (50 bar max.) |
| 6 | 1.000 | 1.750 | 1.750 (50 bar max.) |
| 8 | 1.250 | 2.500 | 7.500 |
| 10 | 1.750 | 3.250 | 7.500 |
| 12 | 2.500 | 4.000 | 7.500 |

Table 2: Price Levels of High Pressure Calibrations in USD.

*With a local in house low pressure test the performance meters operating at higher pressures can be judged or predicted on a financially attractive manor.*

## High pressure

For high pressure testing 2 major solutions are available:

In-line measurement where natural gas is taken from a pipeline and by-passed over an installation. If variable a pressure is available, the calibration can be done at the same conditions as in the field. Since natural gas is explosive, special precaution procedures have to be met. These installations mean a multimillion dollar investment

In loop measurements; gas is circulated using a blower, other gases can be used. By varying the pressures field situation are being simulated. Particularly $CO_2$ becomes popular for this purpose. For loops using compressed air – not considered in this document due to lack of density and Reynolds similarity- the investment are typically less than one million.

Figure 7 and 8 Inline and loop facility

The investment needed for a compressed $CO_2$ loop is about half the price of a compressed air loop, since the temperature stabilization is done in a very efficient way by injecting and vaporizing fluid $CO_2$.
Since the compromises to be made by using compressed air are significant, the use of compressed air as substitute of high pressure natural gas is not further discussed in this paper.

## $CO_2$ as a test medium

As stated before the behavior of turbines is strongly influenced by operating conditions. For this reason calibration should be done as close as possible to the density, viscosity and Reynolds number to give reliable test results. Only when these conditions are close to field conditions `dynamic similarity ` is met and calibration results can be used.
Terasen Gas Inc. in Canada in 2003 did an investigation over a number of industrial gases and came to the conclusion that only $CO_2$ could be used as a test medium to substitute high pressure natural gas. The major advantage of $CO_2$ over air is the closer Reynolds number and density match to natural gas. Additional advantage is densities can be met at lower operating pressure making a $CO_2$ installation safer and less complicated.
A third fact making the installation less complex and cheaper is the absence of a heat exchanger. In all loop designs the energy to run the blower will finally end as heat warming up the installation. The $CO_2$ used for the loop is stored in a vessel in liquid phase, by accurate dosing the amount of fresh $CO_2$ just behind the blower straight

mixing into the gas, the temperature can be controlled within close tolerances and with short response time.
A third party, Southwest Research Institute, did a comparison with six turbine meters for natural gas custody transfer for 2 different turbine meter brands. The sizes tested were 4, 8 and 12 inch. The medium was CO2 and natural gas. Densities varied between 3 and 23 bar natural gas conditions. In general all results were matching within 0.15% over the full range.

In close cooperation with Terasen Gas a CO2 type of test bench is designed which will be commercially available from the mid of this year. As emphasized before, the CO2 testing is the only proven alternative for high pressure natural gas.

## Combining low and high: the best of two worlds

Low pressure testing might not be the best option for calibrating, it still is perfectly suited for monitoring and verifying a meter once it has initially being high pressure calibrated.

One of the major advantages of the low pressure tests it is very sensibility for changes in bearing behavior.


The procedure could be following:

1) A new meter is calibrated at low (air) and at high (CO2) pressure. Curves are used to generate a correction at operating conditions;
2) Meter is low (air) tested after 2-5 years of service. The service period depends on gasquality and maintenance;
3) If the low pressure result is within a band of 0.5 % the high pressure calibration is still applicable;
4) If the low pressure result is out of span the meter probably needs new bearings step 1) should be done again.

Figure 8: combining high and low pressure

With a low pressure installation with a capacity of 2500 m3/hour 98% of the low pressure custody transfer market is covered. Typical calibration cost could be as low as 50 Euro per meter.
A CO2 installation with a capacity of 1600 m3/hour simulating a Natural Gas pressure of 16 bar could cover 95% of all high pressure calibrations for custody transfer. Typical calibration costs could be as low as 250 Euro. This is more than 10 times cheaper

than a similar calibration on a Natural Gas bench in Europe, not even taking into account the logistic complexity and time consuming of shipping.

## Summary

Increasing prices of crude oil and natural gas, is pushing gas companies, governments, end users to consider the use of accurate calibration and testing equipment and procedures. Directives are re-written to become a guideline to achieve these goals and secure a fair trade between all the parties involved.

In Europe, the calibration of gas flow meters has become common practice over the years. As a result of this, the low pressure calibration techniques have improved and become within reach (financial) for a wide range of users. Latest development is the *"remote verification of test benches"* reducing the maintenance significantly.

Research and practical experience has shown that calibrations using atmospheric air are only suitable for meters used below 4 bar. The latest directives and standards require or at least emphasize to perform a calibration close to the actual operating pressure (density).

Unfortunately is the global capacity of the existing high pressure test benches too small to cover the need. As a consequence, alternatives are developed. The most promising concept is using compressed CO2 as medium due to the perfect match of essential parameters like density and Reynolds number. Test carried out by several institutes like South West Research Institute, show a match within 0, 15% over the full flow and pressure range compared to natural gas.

In cooperation with Terasen Gas Company, Vancouver Canada, a commercial CO2 loop is developed. This loop concept is approved by Measurement Canada and NMi and will be available by mid-2007. The advantages of this new CO2 concept are significant and in terms of investments affordable for medium size gas companies and government institutes.

To reduce the cost of high pressure (re)-calibrations, a combined low pressure / high pressure set up can be used. To improve the validations of the results, it is essential that all test benches involved (low and high pressure) are traceable to the same standards (for instance NMi, Netherlands).

Reference and links


- Guide to the Expression of Uncertainty in Measurement 1995;
- Carbon Dioxide as a test Fluid for Calibration of Turbine Meters (SwRI) 2006;
- Effects of line pressure on turbine meter measurement accuracy between 30 and 700 psig in Natural Gas (GRI) 2003;
- Measurement of Gas by Turbine meters (AGA) 1996
- AGA 7 (AGA) 2006;
- EN 12261 (NEN) 2006;
- EN 12480 (NEN) 2006.


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