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Vortrag 10

Der neue Closed Loop pigsar und dessen projektierte Messunsicherheit

The new Closed Loop pigsar calibration facility and its design uncertainty

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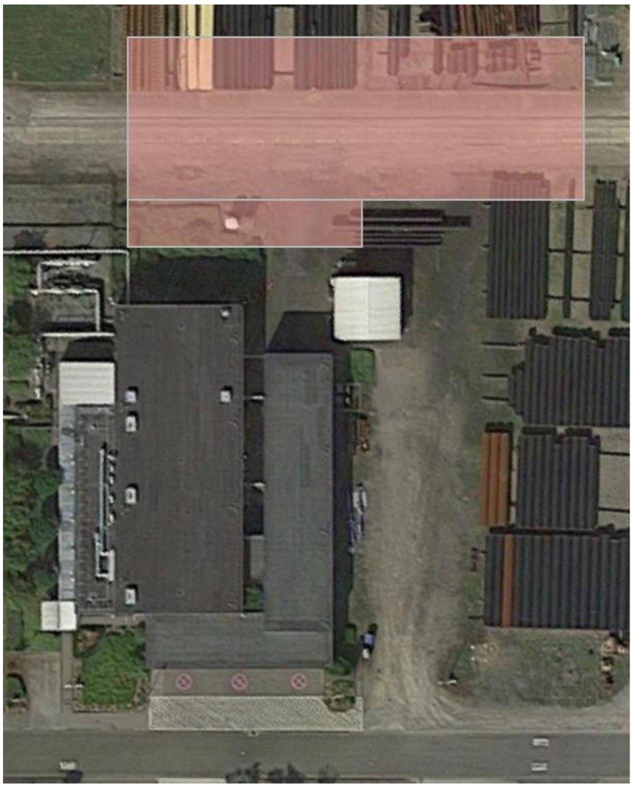
Introduction

The pigsar high-pressure calibration facility is located in Dorsten at the gas pipeline that transports natural gas from the Netherlands to the German Ruhrgebiet. The facility utilizes the gas bypassed from the main pipeline during calibrations. Recently, the green light was given for the construction of an extension to the present calibration facility, called Closed Loop pigsar (CLP). The new CLP has become necessary due to changing customer demands. On the one hand customers require from calibration facilities to be more flexible with respect to delivery times. On the other hand market demands require an expansion of operating ranges with respect to pressures and flowrates. The CLP will be constructed in a separate building on the pigsar site and will be integrated in the existing gas transportation infrastructure. The left-hand side of Figure 1 shows an aerial image of the current pigsar facility, in which the area of the new building has been projected. On the right-hand side the functionalities of the existing and new facilities are schematically depicted. Utilities and logistics will be shared with existing facility, which will enable the new facility to make a flying start.



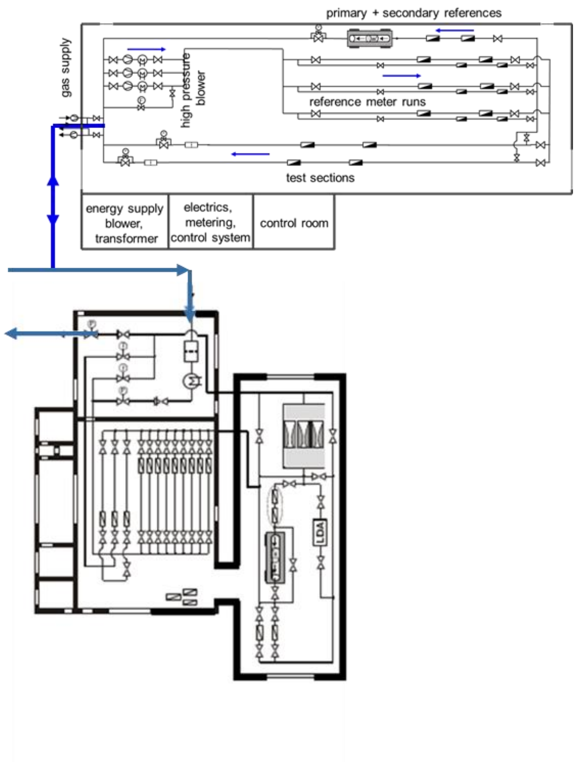


Figure 1: Aerial view (left) of the current pigsar facility and the projected space for the Closed Loop pigsar Calibration Facility. On the right-hand side the connections between the gas transportation line and the existing and new facilities are schematically displayed.

The pigsar facility plays a crucial role in the dissemination of the national high-pressure m³ natural gas and the European harmonized m³. Both national and international high-pressure gasmeter calibration facilities are traceable to the German national m³ located at pigsar.

One of the key performance parameters of a test facility is its Calibration and Measurement Capability (CMC), i.e. the expanded uncertainty (k=2) that can be achieved for a near ideal instrument under test. As the CMC will be influenced by the construction and the modus operandi of the test facility, special care has been taken to design the traceability chain with a minimum number of links. The design traceability chain will be used to evaluate the achievable CMC for new facility. The method is relevant for other facilities that need to be traceable to the (harmonized) high-pressure m^3.

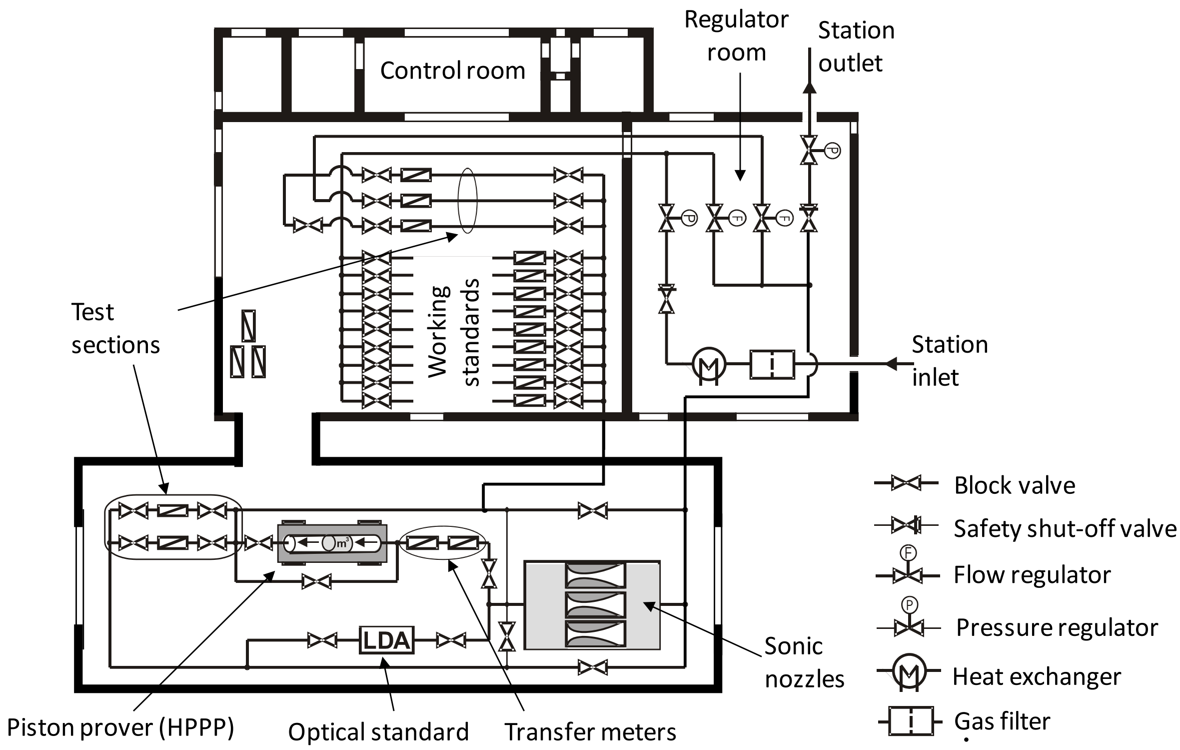


Figure 2: Schematic view of the current pigsar facility. Compared to Figure 1 the diagram was rotated 90° clockwise.

pigsar's calibration facilities

Figure 2 gives a schematic overview of the current pigsar calibration facility. After entering the station inlet, the natural gas is first cleaned in a cartridge filter and then preheated. During the calibration, the preheater also controls the temperature. Between heater and the pressure regulator two safety shut-off valves protect the test facility against excess pressure. Downstream of the pressure regulator the gas flow is divided into a gas stream which is used for calibration and an internal bypass stream. The flowrate is controlled further downstream in both gas flows, shortly before they join up again ahead of the station outlet. The piping configuration was optimized such that gas volume between the working standards and the test meters is reduced to the minimum, which minimizes the line-pack effect. The gas meters to be calibrated, including upstream and downstream straight lengths provided by the customer, can be installed on a total of six test meter runs with a length of up to 22 m. The specifications of the calibration facility are listed in the right-hand column of Table I. A more extensive description of the facility can be found in [1]. The PTB test installations (piston prover HPPP, optical standard, transfer meters, sonic nozzles), shown in the bottom part of Figure 2 are permanently integrated into the pigsar piping system in metering room which was added in 2003 [2].

All measuring variables are traced back to the national SI base units meter, second, kilogram and Kelvin. Thanks to direct access to the national standards of the PTB and the special design of the test facility a very low measurement uncertainty of 0.13% to 0.16% (depending on flow) can be provided.

Table I: Target specifications of the new Closed Loop pigsar versus the existing calibration facility (specifications subject to change during development of the CLP-project)

	New Closed Loop pigsar	Current bypass pigsar
Actual volume flowrate	40 – 22 000 m^3/h	3 – 6 500 m^3/h
Absolute pressure	8 – 65 bar	17 – 50 bar *
Meter diameter	DN200 – DN600 mm (8” – 24“)	DN50 – DN 400 mm (2” – 16”)
Flanges and pressure classes	ANS150 – 1500, PN 16 – 64 **	ANSI 150 – 1500, PN 16 – 64 **
Length of test section	24 and 33 meter	8 – 22 meter
Fluid	natural gas	natural gas
CMC uncertainty (k=2)	0.13% – 0.18%	0.13% – 0.16%
Reference turbine meters	3 x 6” G400 + 3 x 20” G6500	4 x 4” G250 + 4 x 8” G1000

* 8 – 17 bar available on request ** Other flanges and pressure classes upon request

New Closed Loop

Due to the marked demands it was decided to strengthen the capabilities of pigsar at higher flow rates, higher pressures and lower pressures. Furthermore, customers require pigsar to be in total more flexible. As possibilities in high pressure gas transport systems generally are limited, the design of a so-called closed loop system seemed to be a good option.

As the existing pigsar facility was designed for maximum flow rate of around 6500 m^3/h and was not designed to minimize the pressure loss over the facility, it turned that it makes no sense to modify existing pigsar itself to a closed loop system. Instead it was decided to build an independent closed loop system parallel and close to the existing pigsar (see Figure 1). The operation of both systems can be performed independent of each other and makes pigsar more flexible. The Closed Loop pigsar (CLP) will be connected to the high-pressure gas transport system in or close to the so-called regulator room (see Figure 1) of pigsar to fill (pressurize) or empty (depressurize) the CLP. For the filling and emptying processes new compressors will be installed to pressurize the CLP up to 65 bar and to depressurize the CLP down to 8 bar, the lowest operation pressure, or to ambient pressure for repair works or installation of customer meters in the test sections.

The CLP is graphically displayed in Figure 3. On the left-hand side at the top the blowers and heat exchangers are shown. The heat exchangers are necessary to remove the heat coming from the blowers. Water will be used as cooling fluid. The gas flows through the reference meters (MM) first and then through the meters under test (MuT) before returning to the blowers. At the top of Figure 3 a test line for primary and secondary references is shown, which has already been nicknamed PTB test line. Table I gives an overview of the target specifications of the new CLP, which are much wider than the specifications of the current facility.

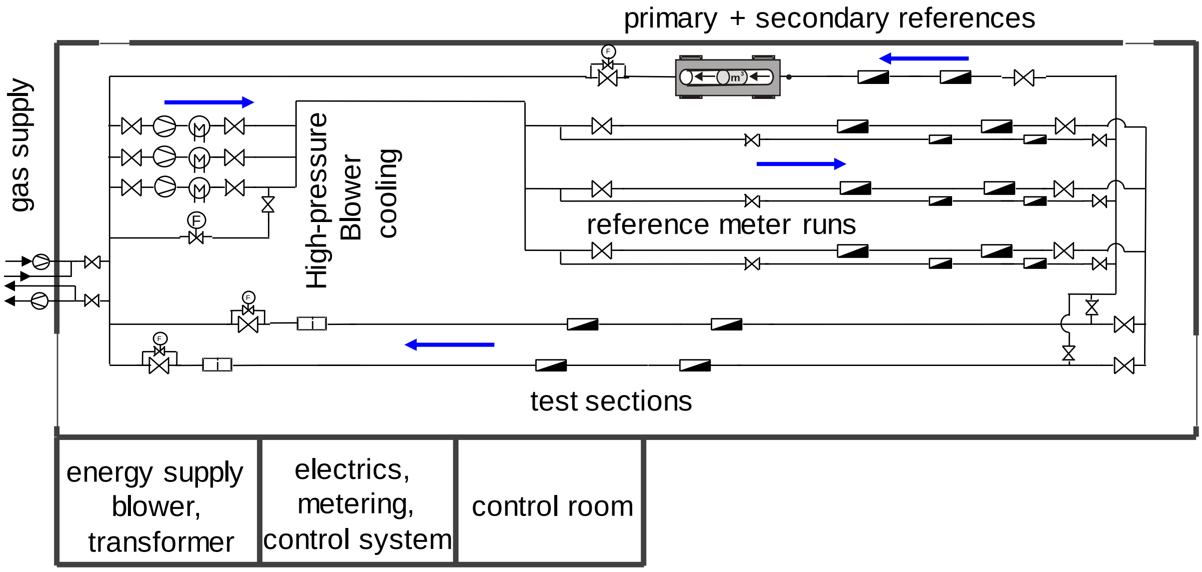


Figure 3: Schematic lay-out of the Closed Loop pigsar Calibration Facility. The different functionalities and utilities are marked in the drawing.

The main ideas behind the construction of the CLP are as follows:

- Calibration must be possible of 20” USMs up to their Q_{max}, which is around 22.000 m³/h for the meter types currently available, at a gas pressure of up to 65 bar.
- The pressure raise of the blowers shall be such that at these maximum conditions a serial installation of two USMs with 2 flow conditioners can be calibrated.
- According to the characteristics of the high-pressure blowers and the pressure loss in the loop it will be possible to calibrate also 24’’ meters or bigger at lower gas pressures and lower pressure losses. Exact values regarding the final capacities cannot be given at this stage.
- The reference meters will be dimensioned to potentially reach 30.000 m³/h or a bit higher. The aim is to reach a minimum flowrate of 40 m³/h, which will allow the calibration of a G2500 meter in the range of 1:100 or a G1600 meter in the range of 1:50
- Currently 6 reference meter runs are planned, 3 times 20’’ G6500 and 3 times 6’’ (size not clear yet G1000 / G650 or G400). Turbine meters will be used as reference meters; in a later stage ultrasonic meters will be installed upstream for check purposes.

- Two test sections are foreseen, one for the calibration of meters under test (MuT) up to 16'' with a designed length of 24 m and one test section for the calibration of meter sizes of 20'' or greater with a designed length of 33 m.
- A third meter run is foreseen for the installation of transfer meters or secondary reference meters or potentially new primary meters. This run will be used for the traceability, i.e. for the calibration and regular checks of the reference meters.

The main challenges during the design and construction phase will be to minimize measurement uncertainty, to optimize the gas and energy management, safety issues, minimize pressure losses and to optimize the construction with regard to future operation.

Current traceability chain

The current German traceability chain is schematically depicted in Figure 4 under the yellow header reading "Existing traceability chain". The primary device is the piston prover (blue rectangle) in which a free moving piston travels through a honed cylinder, which is approximately 250 mm in diameter. The piston can travel at a maximum speed of 3 m/s over a length of 6 m. Due to inertia effects of the piston the effective measurement length is 3 m. The passing of the moving piston is detected by switches that are mounted in the wall of the prover. The dimensions of the prover are calibrated every 5 years, which makes it traceable to the SI unit meter (red rectangle). Two downstream 4" G250 reference turbine gasmeters (green) are calibrated in series using the piston prover. In order to obtain stable conditions, the flow is diverted through the sonic nozzle bench downstream of the two turbine meters. With these reference meters four parallel 4" G250 working standards (turbine master meters, yellow rectangle) are calibrated. The 3" G160 master is taken out of the master section and directly calibrated at the piston prover down to 3 m³/h. With the four G250 master meters two 8" G1000 transfer turbine gasmeter (green rectangle) are calibrated in series, which is used to calibrate four parallel 8" G1000 turbine master gasmeters.

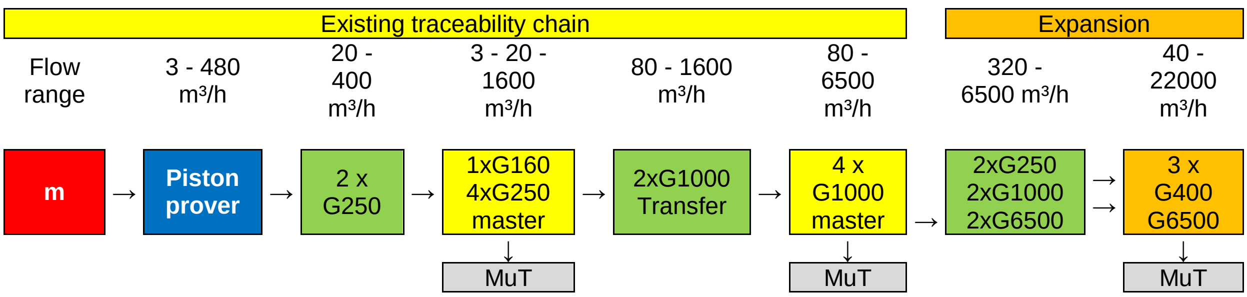


Figure 4: Schematic representation of the current German traceability chain for high-pressure gas flow measurement and its future expansion. The master meters (yellow and orange) are traceable via transfer standards (green) to the piston prover (blue) and the meter (red). The meter under test is calibrated by using a combination of master meters.

The meters under test (MuT) are calibrated using a combination of master meters that matches the desired flowrate. The whole facility can operate between 17 and 51 bar absolute pressure. The masters are calibrated at 17 and at 51 bar absolute pressure. The curves at the intermediate pressures are obtained by interpolation in the Reynolds domain.

Expansion of the traceability chain

For the new CLP facility, the current traceability chain needs to be expanded to lower and higher pressures and to higher flowrates. This is shown in Figure 4 under the orange header "Expansion". At 17 and 51 bar pressure the existing two G1000 transfer meters and two new G6500 transfer meters will used to make the CLP standards traceable up to 6500 m³/h, see Figure 6(b). Using two or three CLP master meters in parallel the G6500 transfer meters can be calibrated up to 10000 m³/h, after which the master meters can be calibrated up to 10000 m³/h. This extra step, which is called bootstrapping, will lead to a slightly higher measurement uncertainty for the upper range of the master meters. It is possible to avoid this step by overloading all references by 10% to 15%. The overload flowrate according to MID Annex IV [7] is 20% above Q_{max}. The calibration curve at 65 bar is achieved by interpolating the calibration curves in the Reynolds domain. At 65 bar the maximum flowrate of the individual master meters is 7400 m³/h.

At this moment, it is possible to operate the piston prover and the two references (4" G250) down to 8 bar, which will be particularly useful for the calibration of the lower pressure range of the CLP. At this pressure the flowrate is limited to approximately 400 m³/h. This will be adequate to calibrate the CLP masters in the low end of their operating ranges. The curves at higher flowrates are obtained by interpolating in the Reynolds domain.

Future developments on high-pressure gas flow traceability

Parallel traceability chains

Basically, there are two independent primary references located at pigsar: the HP piston prover and the optical reference. The piston prover has the lowest uncertainty. The optical reference measures the gas velocity profile by laser-Doppler anemometry in a well-defined cross section in a pipe, which was made optically accessible [8]. Currently, its CMC (0.22%) is much higher than the target uncertainty (0.13%) of the facility. So, it has finally no significant impact to the total uncertainty at the end of the traceability chain.

The work on the harmonized m³ [10] has shown that it is possible to reduce the measurement uncertainty of a laboratory by using parallel independent traceability chains from different countries. The requirement for success is that the influence of all stochastic uncertainty contributions is smaller than the uncertainty of the traceability chain. This is a requirement that is fulfilled for all European high-pressure gas flow traceability chains.

One of the main research topics within PTB is to copy the procedure for the harmonized m³ on a national level by developing additional independent sources of traceability. The objective is to ensure that the uncertainty for the new CLP will be similar or better than the current CMCs of pigsar. In the sections below two new approaches will be discussed to achieve this goal: sonic nozzles calibrated independently and a new, larger primary standard.

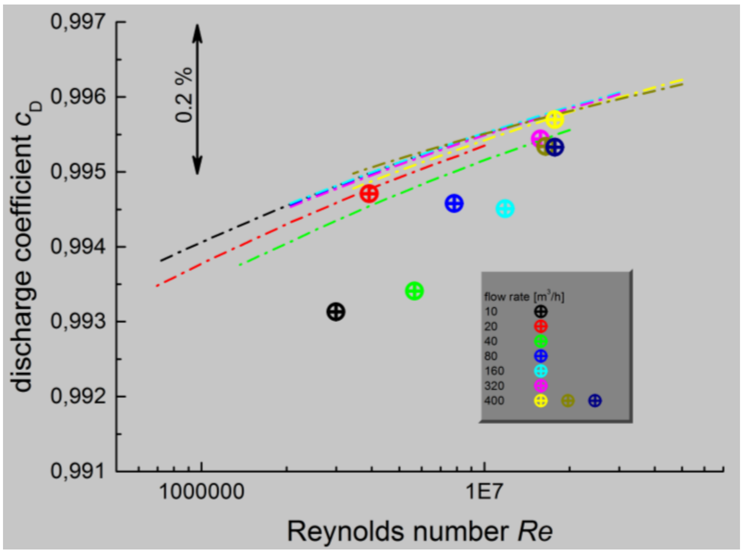


Figure 5: Comparison of calibration values for nine sonic nozzles determined based on their geometric dimensions according [9] and real flow calibration using natural gas at pigsar at 50 bar. The flow rate of the nozzles ranges from 10 m³/h to 400 m³/h (actual conditions). Anticipating an uncertainty of 0.15% for the dimensional based calibration value, differences up to 0.2 % to the real calibration value at pigsar indicate an En-value below 1.

Sonic nozzles at pigsar with independent source of traceability

In the past years, many calibrations have been performed, which show that it is possible to characterize the nozzles by their geometrical dimensions. In combination with the boundary layer theory for laminar and turbulent boundary layers the nozzle behaviour can be described independent of upstream pressure and gas type or gas composition [9]. This will allow the nozzles to be traceable independent of the actual calibration chain of pigsar. An example for prediction of calibration values for such nozzles based on their dimensions in comparison with the real flow calibration at pigsar (50 bar) is given in Figure 5. Additionally, these sonic nozzles can be calibrated at PTB's air flow facilities in Braunschweig operating at atmospheric conditions and up to 16 bar.

The achievable uncertainty of the nozzles based on their geometrical dimensions is under investigation and can be confirmed to be ≤ 0.15% for the time being.

New primary standard

A new development is the design of a new primary standard for high-pressure gas flow measurement, called the PTB HP Comparator. The project has started last year with the construction of a scale model and will take three years to complete. In contrast to the current HP piston prover, the new prover will be an active driven system which is working based on the comparator principle [11]. The target specifications of the new HP Comparator are listed in Table II together with the specifications of the current HP piston prover. The new comparator will be bigger and will be able to operate at higher flowrates than the current piston prover.

Table II: Target specifications of the new HP Comparator versus the current HP Piston Prover

	New PTB HP Comparator	Current HP Piston Prover
Actual volume flowrate	40 - 1600 m^3/h	3 – 480 m^3/h
Absolute pressure	8 – 65 bar	17 – 50 bar *
Tube diameter	DN 600 mm	DN 250 mm
Piston stroke / effective stroke	6 m / 4 m	6 m / 3 m
Maximum piston velocity	1.8 m/s	3 m/s
Fluid	natural gas / air	natural gas
Instrument uncertainty (k=2)	0.10% **	0.05%

* 8 – 17 bar available on request ** Initial value, to be improved

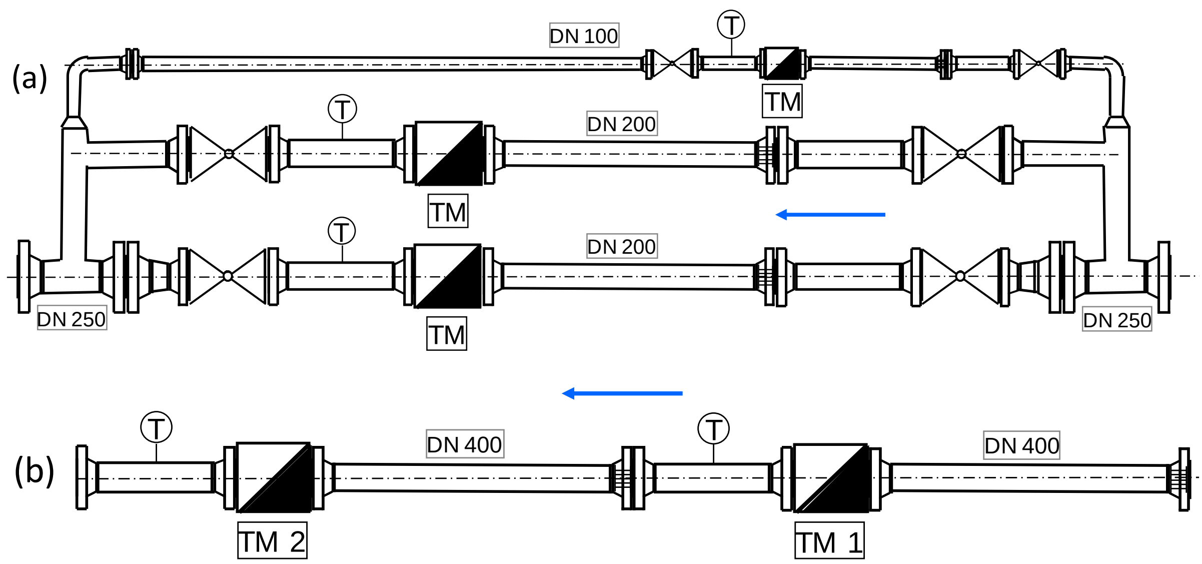


Figure 6: Schematic of the CLP transfer packages. The upper drawing (a) shows the package intended for low and medium operating range of master meters (40 m³/h to 3800 m³/h). The bottom drawing (b) shows the package for the upper operating range of the master (1000 m³/h to 12000 m³/h).

Development of a new transfer package

In order to make the transfer between the old facility and the new facility more easy a transfer package will be designed consisting of one 4” turbine gasmeter and two 8” turbine meters which can be operated either alone or parallel, see Figure 6(a). The package is to be inserted in the PTB test line of the CLP and will be used to calibrate the small master meters and the lower range of the bigger masters. Now only one bootstrap step will be necessary to calibrate the masters in the upper range up to 10000 m³/h, for which a new G6500 transfer package will be built up, see Figure 6(b).

Expected uncertainty for the transfer package based on the three parallel traceabilities

All the activities mentioned above will open the possibility to build pigsar’s traceability on three independent traceability chains with a lower uncertainty. The method will be identical to the method used for the harmonized m³ in the EuReGa framework [10]. The “knot point” to combine all the three sources of traceability will be the new transfer package. Figure 7 illustrates the basic traceability scheme down to the unit provided by the transfer package. According to the uncertainties for the calibration value of the transfer package by the three different chains, the combined (harmonised) uncertainty will be 0.0664 %. For the application of the transfer package we consider additionally a value for reproducibility of 0.05% for each of the parallel meter (see Figure 6a). As the reproducibility of two meters used in parallel can be considered as uncorrelated, we get a final uncertainty of 0.075% for the transfer of the unit.

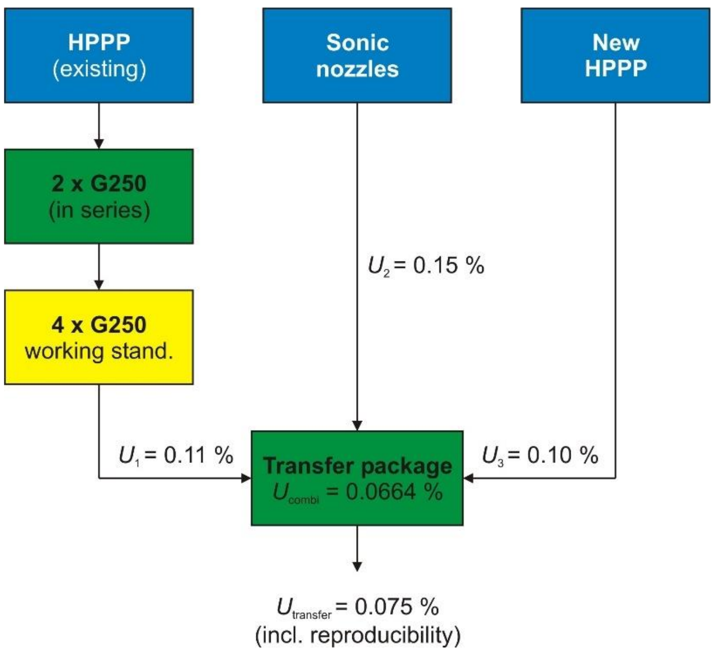


Figure 7: Effect on the final uncertainty for the unit of volume/flow rate provided by the transfer package based on calibrations with three independent sources of traceability. The combined uncertainty is determined according to [10]. Finally, for the uncertainty of the transfer package, a reproducibility of 0.05 % is considered for each of the two parallel G1000 transfer meters (see figure 6).

Calibration model

The calibration method is the so-called master meter method in which a meter under test is compared with a reference meter (master). The comparison is based on the mass conservation principle: the same mass of gas flows through both meters under conditions that are as stationary as possible. In addition, a small correction is applied for line-pack effects. The process is schematically depicted in Figure 8. Both meters are volume flow meters which produce pulses proportional to a certain volume increment. The pressure is measured at the P_r point on the meter and behind the meter there is a thermowell in which the temperature is measured. The conversion between volume flow and mass flow is obtained by using a real gas law for which pressure, temperature and the gas composition are inputs. The real gas factor is computed using the S-GERG algorithm [4] for the existing facility. For the new CLP, a more complex algorithm like AGA-8 [5] or GERG2008 [6] will be used.

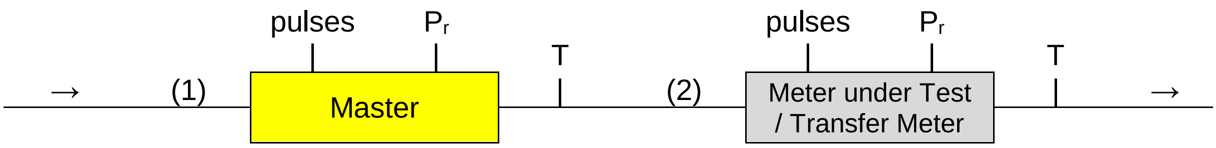


Figure 8: Schematic drawing of the calibration process. P_r is the pressure reference point at which the pressure is measured. T is the temperature measurement point. Pulses are directly collected from the turbine wheel of the gasmeter. At the position of the Meter under Test Transfer Meters can be mounted.

The calibration is performed in the operating range of the MuT. Objective of the calibration is the evaluation of the deviation (error) of the MuT, which is defined as the relative deviation

$$e_i = \frac{Q_{i,MuT}}{Q_{ref}} - 1$$

expressed in %, of the volume flowrate $Q_{i,MuT}$ indicated by the MuT and the reference volume flowrate Q_{ref}, which is the corrected flowrate of the master meter MM. By the same definition

$$Q_{ref} = \frac{Q_{MM}}{1 + e_{MM}}$$

where Q_{MM} is the uncorrected flowrate indicated by the master meter and e_{MM} is the deviation of the master meter applicable to the calibration conditions.

During calibration of the master meters a transfer meter takes the position of the meter under test. The calibration is performed as if the transfer meter is the MuT which results in a deviation $e_{Tr,MuT}$. However, the deviation of the transfer meter from the previous step in the traceability chain is $e_{Tr,ref}$. Now the new deviation $e_{MM,new}$ of the master meter is obtained from

$$e_{MM,new} = (1 + e_{MM}) \frac{1 + e_{Tr,ref}}{1 + e_{Tr,MuT}} - 1$$

The above equation is a simple correction formula to implement the re-calibration curve in the master meters. If the master meter deviation can be reset to zero, the first term of the right-hand-side of the equation equals unity.

The modelling of the calibration process is done similar to [3]. Basis is the integral formulation of the mass conservation law applied to a fixed volume V between the master meter and the MuT. The fluid enters V via the master meters and leaves V via the MuT. The change in mass in V is the difference between the mass flows through MM and MuT. For a completely stationary process the mass in V will remain constant. Although calibration processes are designed to be stationary, a correction will be necessary especially at low flowrate. This is called the line-pack correction. In this case we will consider one MuT that is calibrated one MM. Now the modified equation (6) from [3] becomes:

$$e_{MuT} = \frac{\rho_{MuT}\, N_{MuT} / I_{MuT}\, \tau_{MuT}}{\frac{(\rho_{start} - \rho_{end})\, V}{\tau_V} + \frac{\rho_{MM}\, N_{MM}}{I_{MM} \tau_{MM} (1 + e_{MM})}} - 1$$

Where N is the integer number of pulses collected during a calibration interval τ and I is the impulse factor of the meter [pulse / m³]. The density ρ is a function of pressure p, the (Celsius) temperature t and the gas composition x:

$$\rho = \rho(p, t, x) = \frac{pM}{RZ(T_0 + t)}$$

Where M is the average molar mass of the natural gas, R is the universal gas constant and T_0=273.15 K is the absolute temperature corresponding to 0°C. Z is the real gas factor, which gives the deviation from the ideal gas. The equation of state used to compute Z from p, t and the gas composition x, is the S-GERG algorithm [4]. The pressure at the master meter is measured by the absolute pressure at the MuT and the pressure difference between MM and MuT: $p_{MM} = p_{MuT} + \Delta p$.

Uncertainty budget

The above mentioned mathematical description of the calibration process, was programmed into a Monte Carlo Simulator described in [3]. Although not the main subject of the paper, the authors present an extensive uncertainty evaluation utilizing Monte Carlo methods of a calibration of a gas meter using two reference meters in parallel. In the paper 44 input quantities are listed: reference flowrate, pressures, temperatures, pulse counting, time interval measurement and gas composition. The reference flowrate appears to be the greatest uncertainty contribution (order 10^{-3}), the individual components of the gas composition have the smallest contribution of order 10^{-7}.

This exercise was repeated with the above calibration model, however without considering the individual components of the gas composition as these are four orders of magnitude smaller than the dominant uncertainty contribution. All uncertainties are entered as standard uncertainties (k=1). The uncertainty of each influence factor is the root-sum-square of the known uncertainty sources. For the purpose of the uncertainty analysis, the real gas factor Z has been split into $z_0 = 0$ and Z_i, such that $Z = z_0 + Z_i$. The uncertainty of the algorithm is attributed to $U(z_0) = 0.1\%$, which takes care of the correlations between the Z values used at the different measurement positions. The temperature and pressure influence on the real gas factor was obtained by numerical differentiation of Z with respect to t and p, which gives for the pressure and temperature dependent uncertainties of the real gas factor

$$U(Z_i) = \sqrt{\left(\frac{\partial Z}{\partial p}U(p)\right)^2 + \left(\frac{\partial Z}{\partial t}U(t)\right)^2}$$

The result of the uncertainty analysis is displayed in Table III. The input parameters have been categorized by the order of magnitude they contribute to the overall uncertainty. The reference flowrate (i.e. traceability) gives the highest uncertainty contribution. The repeatability of the meter is an order of magnitude better than the traceability. Please observe that this situation is different from other metrological fields where the repeatability of the calibrated instrument gives a much higher uncertainty contribution than the uncertainty of the reference.

Table III: Order of magnitude uncertainty contributions of the calibration of a high-pressure volume flow gasmeter

Input quantities	Order of magnitude uncertainty	Source
Reference flow	10^{-3}	Traceability
Delta pressure and temperature	10^{-4}	Process
Repeatability of the meter under test	$10^{-4} \sim 10^{-5}$	Repeatability
Pulse counting	10^{-5}	Process
Pressure p_{MuT}	10^{-6}	Process
Time interval measurements	10^{-6}	Process
Compressibility algorithm	10^{-6}	Process
Gas composition components, from [3]	$10^{-7} \sim 10^{-8}$	Process

For the calculation of the achievable uncertainties, the contributions have been subdivided in three categories: traceability, process conditions and repeatability. During all traceability steps the same type of instruments are used, of which the uncertainties are practically equal. So we will use a single uncertainty value for all process based uncertainty contributions together. In order to evaluate the contributions from the different categories the above formula for e_{MuT} was programmed into a Monte Carlo Simulator. The result is that the expanded ($k = 2$) uncertainty contribution to e_{MuT} of all process variables equals $U_{process} = 0.056\%$. The uncertainty of the MuT due to repeatability of successive measurements is evaluated at 0.01%.

Unit			m		Type A	Type B	Total	**CMC**
			|					
Long-term stability for CMC			|					0.075%
			↓					
Primary reference			Old PP			0.05%	0.050%	
			|				|	
Process			|			0.056%	0.056%	
			↓				↓	
Secondary reference		4" G250 TM	4" G250 TM		0.01%	→	0.076%	
			|				|	
Process			|			0.056%	0.056%	
	↓	↓	↓	↓			↓	
References	4" G250 TM	4" G250 TM	4" G250 TM	4" G250 TM	0.01%	→	0.095%	
			|				|	
Process			|			0.056%	0.056%	
			↓	↓			↓	↓
Transfer Meter		2 x	8" G1000 TM	MuT	0.01%	→	0.110%	**0.134%**
			|				|	
Process			|			0.056%	0.056%	
	↓	↓	↓	↓			↓	
References	8"G1000 TM	8"G1000 TM	8"G1000 TM	8"G1000 TM	0.01%	→	0.124%	
			|				|	
Process			|			0.056%	0.056%	
			↓	↓			↓	↓
Transfer Meter		2 x	16" G6500 TM	MuT	0.01%	→	0.137%	**0.156%**
			|				|	
Process			|			0.056%	0.056%	
		↓	↓	↓			↓	
References		20" G6500 TM	20" G6500 TM	20" G6500 TM	0.01%	→	0.148%	
			|				|	
Process			|			0.056%	0.056%	
			↓	↓			↓	↓
Transfer Meter			Transfer	MuT	0.01%	→	0.159%	**0.175%**

Figure 9: Evaluation of the CMCs (k = 2) of pigsar's calibration facilities based on the current traceability chain and its expansion for the Closed Loop pigsar. All uncertainties are added by root-sum-square summation.

The evaluation of the uncertainties of the entire traceability chain is depicted in Figure 9. The process starts with the calibration of the piston prover using dimensional references which results in a starting uncertainty of 0.050%. Subsequently, the uncertainties of all traceability steps are added. In this picture the transfer meters and MuT are at the same level because they are calibrated by the same references. However, in order to achieve the CMC an experience-based additional uncertainty for the long-term stability of 0.075% needs to be added. The re-calibration of the traceability chain is done in a matter of weeks, the CMC is calculated for a period of 3 years. The results of the computations confirm the present CMCs of pigsar and show that the target CMCs of the new CLP are achievable.

Consequences for the harmonized m³

The fact that the uncertainty from the repeatability is so much smaller than the uncertainty of the traceability allows reduction of the uncertainty when using more parallel traceability chains [10]. With the new CLP pigsar will be able to participate additionally in the 8 bar intercomparison. Before 2014 EuroLoop was the only laboratory capable of handling the high-flowrate range over 50 bar. The new facility of FORCE covers the same range of pressures and flowrates and participated in the harmonization exercise of 2014. The expansion of pigsar's measurement capabilities into higher pressures and higher flowrates will mean that this range will be covered by an additional laboratory. More parallel traceability chains will lead to a potential reduction of measurement uncertainty in the high-pressure high-flowrate range. For the high-pressure gas flow market this will mean that even lower uncertainties can be offered by the laboratories operating under the EuReGa agreement.

Summary

In 2017 the construction of the new Closed Loop pigsar (CLP) facility was commissioned, which can be operated parallel to the existing pigsar facility. Its expanded measurement capabilities require the present traceability chain to be extended. The evaluation of the design of the facility, the traceability chain and the measurement uncertainties, demonstrates the feasibility of the target CMCs for the new CLP.

In addition, the development of a HP Comparator and the use of sonic nozzles as primary references will enable the design of a shorter traceability chain, which is aimed to result in lower measurement uncertainties.

For the harmonized cubic meter the new CLP means additional coverage for the 8 bar measurements and in the upper flowrate range up to 6500 m³/h at all pressures. This extended coverage will give a broader fundament to the harmonized m³ with potential lower uncertainties for all laboratories participating in the EuReGa consortium.

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