Extension of the pigsar™ high-pressure gas meter test facility: the new “Closed Loop pigsar”

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For almost 25 years the high-pressure calibration facility pigsar™ in Dorsten, Germany, has been operated in a so-called bypass configuration. Changing customer requirements and worsening conditions provided by the high-pressure gas network make it necessary to enlarge the capabilities of pigsar™. It was decided to construct a new Closed Loop pigsar (CLP) calibration facility. This new facility will be operated in parallel and close to the existing facility for gas meters over 12” diameter, while it is intended to calibrate the gas meters below 12” at the existing facility.

One of the key performance parameters of a test facility is its measurement uncertainty. Therefore, special care has been taken during design and planning of the new facility as well as for the modus operandi of the CLP to achieve low uncertainties. This especially regards the design of the traceability chain of the new CLP, the modeling of the calibration processes and the development of a new primary standard by PTB. Evaluations by PTB have shown that measurement uncertainty can be improved quite considerably by combining several traceability chains currently developed and improved by PTB.

1. INTRODUCTION

Vier Gas Services GmbH & Co. KG is the operator of pigsar™, one of the world’s leading high-pressure gas meter test facilities located in Dorsten, Germany. The site is also home to the national standard for high-pressure natural gas measurement – the “original cubic meter” – used in cooperation with the Braunschweig-based Federal Institute of Physics and Metrology (PTB) as the basis for measurement in high-pressure natural gas transmission and trading in Germany. pigsar™ is also a key contributor to the European reference value EUREGA (“European Reference for Gas Metering”). EUREGA unites the independent calibration chains of the Netherlands, France, Denmark and Germany and provides the harmonised reference standard for natural gas trading.

pigsar™ is predominantly used for testing volumetric and mass flowmeters for natural gas transmission and trading. pigsar™ was established in 1993 and has since tested and verified thousands of gas meters installed all over the world. It is also used for calibrating other test facilities in Germany and Europe.

Customer needs have changed in recent years. Apart from more flexibility, there is a growing demand for calibrating “larger” gas meters. Some ultrasonic flowmeters today allow metering stations to be operated with flow velocities of up to 40 m/s inside the gas meter. For meters with a nominal diameter of 300 mm, for example, this corresponds to a volumetric flow rate at operating conditions of around 10,000 m³/h. Moreover, there is an international tendency to design meter runs with a larger nominal diameter. Since the maximum flow rate of pigsar™ is limited to 6,500 m³/h for operational reasons, the operator looked at various ways of increasing the capacity. National and international test facilities built in recent years are all based on the so-called “closed-loop principle”. It has been shown that this principle enables stable meter operation even at high gas flow rates.

2. CURRENT PIGSAR™ CONFIGURATION

At today’s test facility, the gas is taken from an Open Grid Europe (OGE) pipeline operated at a high pressure. It is filtered, preheated, pressure and flow-controlled and...
then passes through the test facility before it is fed back into the OGE pipeline system further downstream at a lower pressure (“bypass principle”). The gas piped through the test facility is used for meter calibration. Figure 1 shows the current configuration. pigsar™ operation is closely coordinated with OGE’s grid control room, which approves the daily start-up of the test facility and – since supply security is of paramount importance – can also disconnect pigsar™ from the OGE grid at short notice, if necessary.

The PTB standards are a significant part of the pigsar™ facility, as can be seen in Figure 1. The piston prover as the national standard for the unit of volume for high-pressure natural gas, the secondary standards and critical nozzles as transfer standards and the new optical standard allow the calibration chain to be relatively short, which gives a low measurement uncertainty of 0.13-0.16 % (k=2), cf. [1, 2]. The current operating parameters are summarised in Table 1.

The existing configuration and mode of operation have proved very successful. However, as described above, new customer requirements in terms of flow rate and flexibility now mean that pigsar™ needs to be upgraded and expanded. Earlier plans to turn the existing test facility into a closed-loop system while also slightly increasing the maximum volumetric flow rate to approx. 10,000 m³/h were rejected because of the high pressure losses this would have meant for the existing plant; the original plant design had not been optimised for pressure losses. A new closed-loop design therefore appeared to be the most sensible solution.

3. THE NEW CLOSED LOOP PIGSAR (CLP)

The design specifications for the CLP are as follows:

- The test pressure range must be between 9 bar and 66 bar abs.
- In this pressure range, turbine and ultrasonic flowmeters sized DN500 can be tested across their entire flow range. For the current type approvals, the required Qmax is therefore around 22,000 m³/h.
- The high-pressure blowers must be designed to allow meter runs fitted with two ultrasonic flowmeters (each with a perforated plate flow straightener) installed in series, or an ultrasonic flowmeter with a turbine flowmeter (each with a flow straightener) to be tested across the entire test range.
- Data acquisition must be designed to allow four meters to be tested in parallel.
- Two test runs (DN400 and DN500) have to be provided. Another test run sized DN200 / DN250 for PTB standards is also needed.
- Testing in the new part of the test facility must not have any influence on parallel tests in the existing test facility.

Table 1: Specifications for the new Closed Loop pigsar facility and key technical data for the current test facility

<table>
<thead>
<tr>
<th>Specification</th>
<th>Closed Loop pigsar*</th>
<th>bypass pigsar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual volume flowrate</td>
<td>40-22000 m³/h</td>
<td>3-6500 m³/h</td>
</tr>
<tr>
<td>Absolute pressure</td>
<td>8-65 bar</td>
<td>17-50 bar</td>
</tr>
<tr>
<td>Meter diameter</td>
<td>DN 200-600 mm (8”-24”)</td>
<td>DN 50-400 mm (2”-16”)</td>
</tr>
<tr>
<td>Flanges and pressure classes</td>
<td>ANSI 150-1500, PN16-64</td>
<td>ANSI 150-1500, PN 16-64</td>
</tr>
<tr>
<td>Length of test section</td>
<td>Approximately 37 meter</td>
<td>8-22 meter</td>
</tr>
<tr>
<td>Test meter runs</td>
<td>2 (3)</td>
<td>6 (7)</td>
</tr>
<tr>
<td>CMC uncertainty (k=2)</td>
<td>0,13%-0,18%</td>
<td>0,13%-0,16%</td>
</tr>
<tr>
<td>Reference turbine meters</td>
<td>3x6” G400 (G1000) + 3x20” G6500</td>
<td>4x4” G250, 4 x 8” G1000, 1x3” G160</td>
</tr>
</tbody>
</table>

*all specifications subject to change
The design values for the CLP as determined “halfway through the detailed engineering” are summarised in Table 1. Figure 2 shows the schematic layout with the five most important plant components:

- Three high-pressure blowers arranged in parallel, each with a maximum output of approx. 950 kW, provide a continuous flow. The flow rate is controlled via the frequency converters of the blower motors. Smaller flows are controlled via internal bypass lines. A heat exchanger is provided for each high-pressure blower to remove the heat generated by the blower.
- Six standard runs are envisaged, see Table 1 for sizes. The large standards are designed to allow volumetric flowrates ranging to above 30,000 m³/h to be meas-

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**Figure 2:** Schematic configuration of the Closed Loop pigsar test facility

**Figure 3:** Aerial view of the existing pigsar™ showing the area designated for the CLP extension. The schematics with the network connection are on the right.
ured, which would allow meters sized G16000 to be tested at the upper end of the test facility’s capacity range. The aim is to achieve 40 m³/h for the lowest volumetric flowrate, which would allow a meter sized G2500 to be calibrated across a measurement range of 1:100 or a G1600 across a range of 1:50. Turbine flowmeters will be used as standard meters, ultrasonic flowmeters will be retrofitted at a later point as reference standards for each standard pipe run.

- Meter run 1 will be sized DN500, but larger meters could also be installed here. Meter run 2 sized DN400 is intended for meters sized DN400 and below. As with the existing pigsar™ system, the piping to the meter runs could also be smaller connecting pipes, which reduces the so-called line-pack effect at smaller flow rates. The meter runs will be long enough to ensure that even were components are connected in series, a sufficiently long upstream straight length is available for ultrasonic flowmeter testing.

- A third meter run sized DN200/DN250 is envisaged for new primary and secondary standards provided by PTB. These meters will be used to calibrate and regularly check the working standards.

- The CLP will be gassed up and depressurised via two high-pressure compressors. Depending on the network situation, the pressure may be raised directly to at least 44 bar from the high-pressure gas pipeline system; a further increase to the desired test pressure (66 bar abs. maximum) can then be achieved with the high-pressure compressor. The entire plant or the test runs can be depressurised down to approx. 17 bar directly into the downstream gas grid. Further depressurisation will require the use of another compressor.

**Figure 3** shows the new plant integrated into the overall station layout. The local logistics and infrastructure will be modified accordingly, also with regard to the larger and heavier test specimens and meter runs to be expected. **Figure 4** is an isometric view of the current design status. The aim is to start meter testing in 2020.

### 4. EXISTING TRACEABILITY CHAIN

pigsar™ plays an important role for the realisation and dissemination of the national cubic meter for high-pressure natural gas flow measurement and the harmonised European cubic meter of natural gas. All national and some international test facilities are traceable to the German cubic meter as determined by pigsar™.

Today’s German traceability chain – shown schematically in **Figure 5** under the yellow bar – is briefly described below. Further details are given, inter alia, in [1, 2]. The primary standard is provided by the piston prover (RPS), see [1]. The geometry of the RPS is re-checked about
every five years and thus traced back to the SI unit “meter”. Two turbine flowmeters sized DN100 / G250 (secondary standards) installed in series are calibrated directly with the RPS, with the downstream flow being stabilised by critical nozzles. The critical nozzles are also used to help with the traceability chain at very low flow rates (approx. <=50 m³/h). The next step then is to calibrate the small working standards of the pigsar™ facility up to 400 m³/h using the secondary standards. They are followed by the four large working standards which are each calibrated up to 1,800 m³/h using a transfer meter G1000.

The test specimens are calibrated with a combination of working standards. Figure 5 shows the current “Calibration and Measurement Capability” (CMC) values. The CMC values are the extended values for the measurement uncertainty (k=2) of a test facility. With an uncertainty of 0.05 % for the piston prover, an uncertainty of 0.056 % for the process conditions, 0.01 % repeatability and 0.075 % long-term stability of the standards, the CMC values for pigsar™ are currently between 0.13 % and 0.16 %, depending on the flow rate, cf. [5].

5. EXTENSION OF THE CLP’S TRACEABILITY AND MEASUREMENT UNCERTAINTY

Given the extended measurement capabilities of the new Closed Loop pigsar test facility, the existing traceability chain must be extended to include lower and higher pressures as well as higher flow rates. Alongside the current traceability chain, Figure 5 also shows the extended traceability chain for the CLP under the orange “Extension” bar.

Calibration of the new CLP standards (orange) will involve the use of two new transfer meter packages. Figure 6 shows two initial designs. The meters of the smaller package (a) can be calibrated against the small working standards of the existing pigsar™ facility with a measurement uncertainty of approx. 0.13 %. This calibrated package (a) is installed into the CLP’s PTB meter run for the calibration of the CLP standards, cf. Figure 2. So the three small CLP standards are calibrated against the transfer package (a) at the full flow range, and the three large CLP standards are each calibrated up to approx. 3800 m³/h. The transfer package (a) will remain installed in the CLP’s PTB meter run between the recalibration cycles and – as with the QM procedures of the existing test facility – will be used to regularly check the working standards of the CLP.

The DN400 transfer package (b) will be calibrated for flow rates of up to 6500 m³/h on the existing pigsar™ and installed into the CLP’s DN400 test run. It will be calibrated further against the three large CLP standards for flow rates of approx. 10,000 m³/h. Then the CLP standards can be calibrated for flow rates up to 10,000 m³/h. This additional step called bootstrapping gives a slightly higher measurement uncertainty for the upper range of these standards, the target value being <= 0.18 %.

At present, the piston prover and the secondary standards (DN100/G250) can be operated down to a minimum pressure of 8 bar, which will benefit the calibration of the CLP in the lower flow range up to about 400 m³/h. In the upper flow range of the CLP, at low pressures, the Reynolds number interpolation method has to be used.

6. FUTURE DEVELOPMENT OF THE TRACEABILITY CHAIN

The implementation of the harmonised European reference standard has shown that measurement uncertainty can be reduced by linking independent calibration chains of different countries. For this to be possible, the influ-
ence of all stochastic uncertainty contributions has to be smaller than the uncertainty of the traceability chain, as is the case with the traceability chains involved in the harmonisation.

One of the research projects at PTB is looking into copying the procedure for the harmonised reference value on a national level by developing additional, independent traceability chains. The aim is to improve the measurement uncertainty of the existing pigsar™ and the new CLP. For this purpose, PTB are currently developing two independent traceability chains, cf. [3]:
- One new, independent traceability chain relies on critical nozzles. The uncertainty achieved here by geometrical measurement, theoretical approaches and calibrations with standards at PTB (up to 16 bar air) is as low as ≤ 0.15 %, cf. [4].
- The other new development is the PTB HD comparator. Unlike the piston prover, this design is a piston-cylinder system with an actively driven piston. A smaller-scale prototype is currently being tested at PTB. The aim here is to provide a new primary standard for the new CLP for the 40-1600 m³/h flow range with a measurement uncertainty of 0.1 %.

These two new calibration chains can be combined with the current calibration chain by using transfer package (a) in Figure 6. In this combination, the measurement uncertainty of this transfer package can be as low as 0.075 %, which would significantly reduce the measurement uncertainty (CMC value) for pigsar™.

7. SUMMARY

The high-pressure gas meter test facility pigsar™ is being extended to include the new Closed Loop pigsar (CLP). The new part of the test facility will be operated almost independently of the natural gas network alongside the existing facility. Planning has been completed and construction work will start in autumn 2018. Meter testing at the new CLP is expected to start in 2020. The new installation will significantly extend the portfolio of services offered by pigsar™; in future it will be possible to calibrate gas meters up to a nominal diameter of DN600 or even larger meters for specific flow rates. The pressure range will also be extended to 9-66 bar (a). At the same time, PTB is conducting several projects to improve the traceability chain for the high-pressure cubic meter of natural gas based on the measuring principle of critical nozzles and a piston-cylinder system (new high-pressure comparator). The aim here is to improve the traceability of high-pressure gas measurement for very large flows with the help of the CLP, while at the same time improving the measurement uncertainty in the existing German traceability chain. By reducing the risk of incorrect measurement, the projects by PTB and pigsar™ will benefit the entire German gas industry.

REFERENCES


Figure 6: Schematic diagram of the new CLP transfer meters. Transfer package (a) is intended for a flow range of 40 m³/h to 3,800 m³/h. Transfer package (b) is intended for a flow range of 1,000 m³/h to 12,000 m³/h (Note: The final details may differ slightly from this diagram)