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Paper

Experiences with Permanent Series Connection of Ultrasonic Gas Flow Meters (USM) in the German Gas Market

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Preamble

The design of metering stations in Germany varies greatly. However, in recent decades, connecting two gas flow meters in series has become established as best practice for many metering stations.

The design was first described in the German verification law “Mess- und Eichverordnung” (Appendix 7, 5.6.7)[1], where two meters with different metering principles were intended to be used. Connecting them in series allows an annual extension of the recalibration period as long as:

1) Both meters have a certified design (type approval),
2) Both meters are calibrated initially,
3) The change of the flow deviation between the two gas meters during operation is less than ±0.5%.

In recent years, the benefits of ultrasonic flow meter technology, especially the low pressure drop and diagnostic capabilities, were the driving force to allow series connections of two USM.

The series connection of two independent USMs is now the favored solution in many metering stations in Germany.

In 2013, the Physikalisch Technische Bundesanstalt (PTB) consolidated end users' experience with connecting USMs in series into the technical guidelines TR-G 18 “Requirement for permanent series connection of two ultrasonic gas flow meters”.

This paper offers an overview of typical USM-USM setups and discusses experiences of recent years.

1. Motivation

Calibrations and periodical re-verifications of fiscal meters are required by national law and/or contractual agreements. These periodical re-verifications ensure that the meters operate within the required accuracy limits. Verification against traceable reference standards is fundamental in fiscal metering.

Contamination is always critical with regards to measurement uncertainty. It is thus very reasonable to define a re-verification period based on application conditions. However, most applications for the fiscal measurement of natural gas measure dry and clean gas without causing contamination.

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[1] c.f. “Verordnung über das Inverkehrbringen und die Bereitstellung von Messgeräten auf dem Markt sowie über ihre Verwendung und Eichung (Mess- und Eichverordnung - MessEV)“; MessEV; 11.12.2014

Ultrasonic gas flow meters have been in use for more than 20 years. The technology provides a high turndown ratio, no pressure drop and bidirectional operation, is virtually maintenance-free and has many valuable diagnostic capabilities. This experience with its application, and reliable re-verification data have allowed re-verification periods to be extended over the last two decades. In Germany and Italy, the current re-verification period is eight years for ultrasonic gas flow meters, compared with the original period of five years[2].

In general, there is a conflict between performance, costs and risk control which operators need to balance out. Custody transfer is always about minimizing financial exposure. It is important to consider the particular application characteristics to determine the appropriate re-verification period. However, since calibration incurs high costs (CAPEX and OPEX), there is a desire to extend re-verification periods. This is particularly interesting for applications with dry and clean gas, where there is a limited risk of changes to the meter.

It has become more and more popular to reduce the risk of gas measurement uncertainty by installing a main and a check meter in series in the metering run. The main meter is used for the fiscal metering of the gas volume and the check meter to monitor and verify the main meter's readings. The online comparison of both meters shows that they are operating synchronously. If the measurement deviation between the two meters shifts, the metering run needs attention. The operators typically use two different meter types for such an installation to avoid common-mode errors. This can be a combination of different technologies such as ultrasonic and turbine meters, or different manufacturers or a different path configuration in the case of two ultrasonic meters.

A combination of two ultrasonic meters is preferred in Germany for today's green-field custody transfer applications or reconstructions of existing metering stations. Operators want to benefit from the diagnostics capabilities of ultrasonic gas flow meters. These facilitate additional application analysis to help understand changes in the process if an online comparison of the serial installation indicates a shift in the meter readings.

Based on these facts, and the positive long-term measurement stability of ultrasonic gas flow meters, the "Physikalisch Technische Bundesanstalt" (PTB) has released technical guidelines TR-G 18 "requirements on permanent serial installations of two ultrasonic gas flow meters"[3]. These guidelines allow the annual extension of re-verification intervals purely based on measurement data verification. Naturally, the guideline is stimulating controversial discussions in the industry – even beyond Germany's borders.

2. Legal Aspects & Overview of the Market View

Several technical standards and recommendations exist internationally to regulate and harmonize the oil and gas market. In Europe, the Measuring Instruments Directive (MID)[4] and the recommendation OIML R 137-1&2 apply to gas measurement with ultrasonic gas flow meters when meters are brought into use. National regulations such as the German law on Weights and Measures (MessEG, MessEV) govern the measuring devices on the market, their use and re-verification.

[2] cf. "Änderung der Eichordnung – Allgemeine Vorschriften (AO-AV) Anhang B (Besondere Gültigkeitsdauer der Eichung) Nr. 7.1 bis 7.5"
[3] cf. "Messgeräte für Gas TR-G 18"; PTB; https://www.ptb.de; 2017
[4] cf. "Measuring Instruments Directive (MID)"; http://ec.europa.eu/growth/single-market/goods/building-blocks/legal-metrology/measuring-instruments/; 2017

The national law is supported by national regulations, instructions or “best practice” guide-lines. One such technical guideline is TR-G 18, published by the “Physikalisch Technische Bundesanstalt” (PTB) in consultation with the calibration-regulating authorities.

Figure 1: visualizes the impact of the international and national standards and regulations on the design of a metering run. A single ultrasonic gas flow meter with its inlet and outlet piping, pressure tapping and thermowell is designed, manufactured, calibrated and installed in line with the MID Type-Examination Certificate (TEC). The two meters including inlet and outlet piping are permanently installed in series in accordance with national regulations and guidelines (Weights and Measures Act and “TR-G 18”).

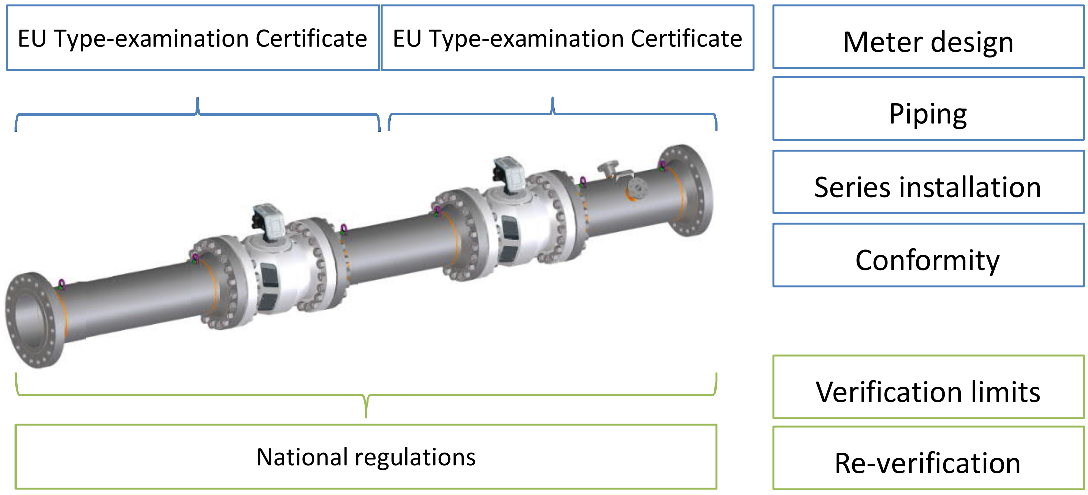


Figure 1: USMs installed in series in accordance with international standards and national regulations

3. Requirements for the Permanent Installation of two Ultrasonic Gas Meters In Series in Fiscal Metering

3.1 The Technical Recommendation TR-G 18

The German Weights and Measures Act legally allows the installation of gas flow meters in series. Based on good experience with ultrasonic gas flow meters, and its re-verification results showing long term stability and insignificant to no error bias shifts, the TR-G 18 has been released as a technical recommendation. TR-G 18 provides guidelines on how to use the German Weights and Measures Act, especially when two ultrasonic gas flow meters are installed: “requirements regarding permanent serial installations of two ultrasonic gas flow meters”.

The technical guidelines determine design-engineering requirements for ultrasonic gas flow meters and their installation, as well as the execution and documentation of the comparison measurement upon commissioning and annual revision.

The verification interval of installations which fulfill all requirements can be annually prolonged on-site, without the need for testing at a flow calibration laboratory.

3.2 Requirements for Design-Engineering, Calibration and Commissioning

Two different ultrasonic gas flow meters react differently to flow conditions, as the ultrasonic path layout captures different segments of the flow cross-section. This is the case if:

- The number of paths is different or
- With the same number of paths
  - The meter is equipped with reflective paths instead of direct paths or
  - A different number of paths are crossed in the same measurement plane

Because of the differences in their design, the meters are expected to react differently in terms of error of measurement if there is a change in the flow profile and/or the piping is contaminated.

Each meter needs to fulfill the requirements of its type examination certificate (TEC) with regards to the installation conditions and needs to be flow calibrated.

One meter can be part of the inlet piping of the second meter as long as this is not in conflict with the TEC of this meter.

According to TR-G 18, flow meters permanently installed in series may optionally have different ultrasonic transducer frequencies or different signal processing algorithms and may therefore have a different sensitivity to acoustic noise in the gas flow. The ultrasonic frequencies are accepted as different if these differ at least by 50 kHz.

It is recommended to calibrate two flow meters installed in series as a complete meter package. Calibrating the inlet piping and both meters as a skit at the same facility and at the same time ensures the best possible synchronization between the two meters. This means that not only the meter but also the meter run is calibrated and adjusted to the lowest possible comparative deviation in the metering run.

3.3 Requirements for Annual Extension of Re-Verification Periods

The German Weights and Measures Ordinance (MessEV) provides an annual prolongation of the validity period if the following requirements regarding the comparative measurement and the documentation are fulfilled:

- Comparative measurement upon commissioning and at least once a year. The corresponding records need to be available without a gap from commissioning on.
- Documentation of fulfillment of the required design-engineering requirements upon commissioning.
- Upon commissioning and during the annual comparative check, a verification test flow rate needs to be maintained above the transitional flow rate Q_t for at least 15 minutes. The two meters' differential pressures can be compared using the flow volume at standard conditions ($V_{a.c.}$) or at base conditions ($V_{b.c.}$).
- The relative speed of sound (SOS) deviation of every single path to the average SOS of each meter needs to be documented upon commissioning and during the annual check.
- The annual comparative measurement needs to take place on site.

With the annual comparative measurement, the deviation between the two meter readings may not have changed by more than ±0.5% compared to the deviation identified and documented during commissioning. It is recommended to compare the standard volumes ($V_{s.c.}$) to compensate for the influences of temperature and pressure.

The relative SOS of each ultrasonic path to the average may not deviate by more than 0.3% compared to the identified and documented deviation of the meter upon commissioning.

If one of these maximum limits has been reached, the metering run loses its calibration validity within six months or when the regular calibration validity of an individual meter runs out. The operator is solely responsible for accurately documenting and verifying meter data. The Board of Weights and Measures needs to be involved only if the defined deviation limits for volume or speed of sound are exceeded.

4. Typical Metering Line Design

Two typical metering run designs have been established for the permanent connection of two ultrasonic gas flow meters in series.

The first option defines the meters as being installed in series with inlet and outlet piping for each meter, see Figure 2: Series installation of two UMS.

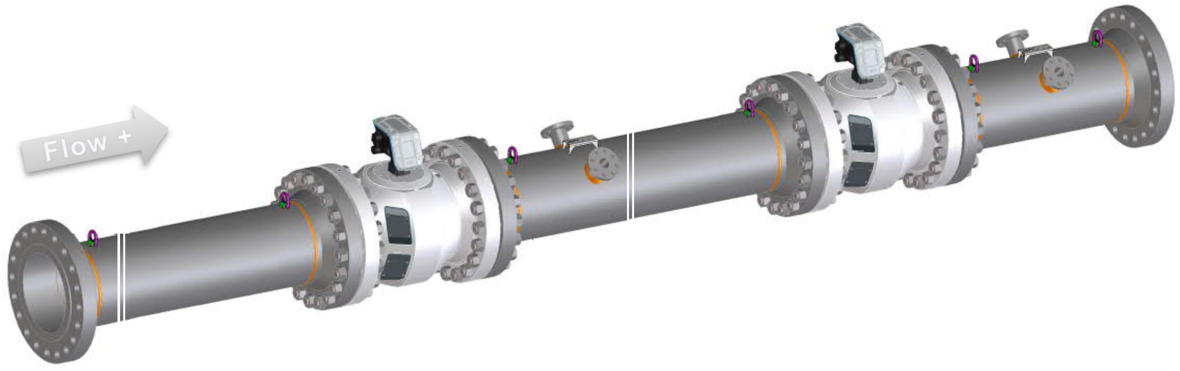


Figure 2: Series installation of two UMS

The design and minimum length of the inlet piping needs to fulfill the requirements according to the TEC of each meter. Both or one of the meters may have a reduced bore measurement section. The inner diameters of the meters and associated piping may be within ±3% if not otherwise limited by the TEC of the meters. Both meters have the temperature measurement location downstream, each close to the respective meter.

The second option is a so called back-to-back installation where the first meter is mounted flange-to-flange with the second meter and so becomes part of the second meter's inlet piping, as shown in Figure 3: Back-to-back installation of two USM below.

Figure 3: Back-to-back installation of two USMs

The design and minimum length of the inlet piping needs to fulfill the requirements according to the TEC of each meter. The first meter must be considered as part of the second meter's inlet piping. Both meters need to be manufactured as full bore meters and the inner diameters of meters and associated piping are recommended to be within ±1%. The temperature measurement location downstream of the second meter is representative of both meters.

The back-to-back metering run design is the most compact design for serial meter installation.

5. Example Results

Since it is becoming increasingly common to build metering lines which conform to TR-G 18, this paper will give two examples of this design and related field experience below.

5.1 Metering Station A

A major German gas distribution company operates several stations with a serial installation of two ultrasonic gas flow meters. The operator uses two different meter brands for the 16 inch pipe line. The typical gas pressure is 78 to 88 bars and the gas temperature is about 20 °C.

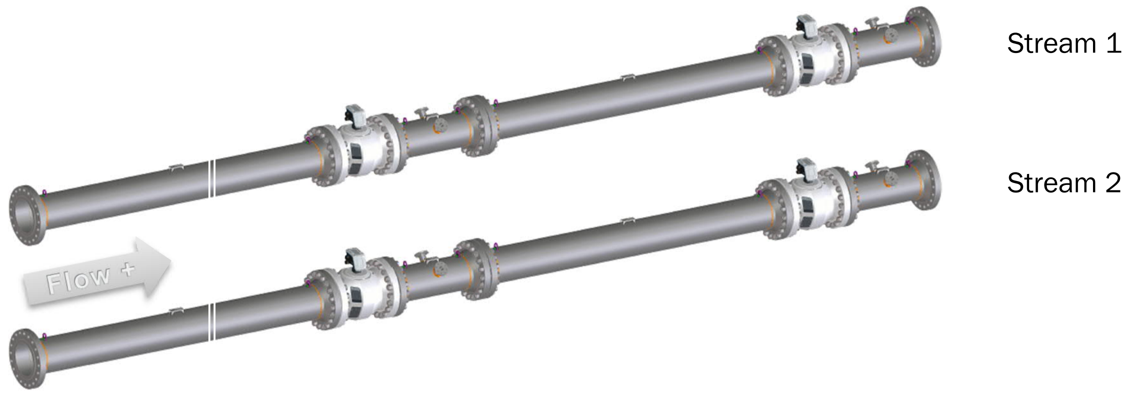
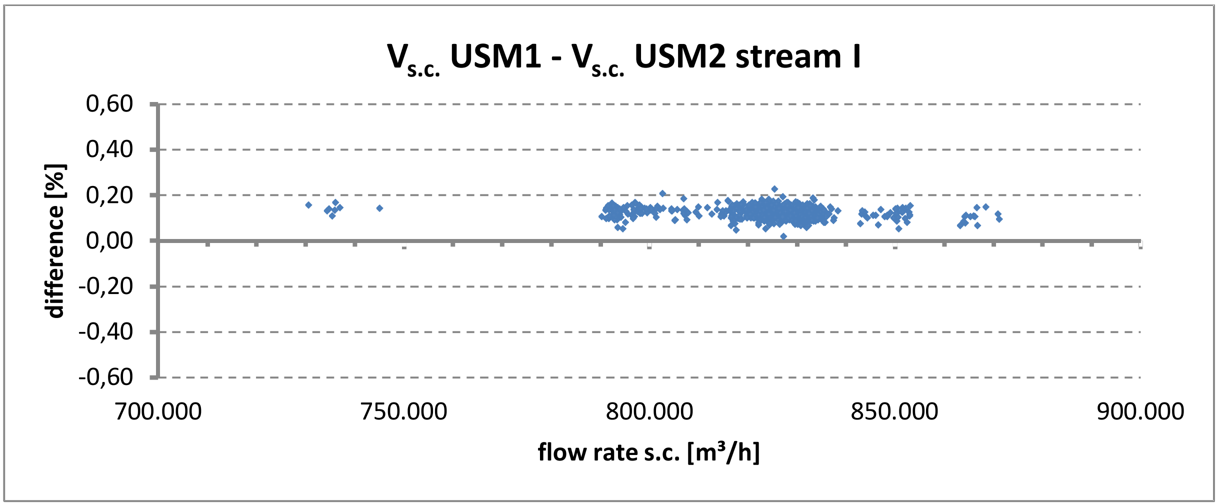


Figure 4: Two USMs installed in series, station A

Figure 4: shows a typical meter run with two streams. The inlet piping for the first meter in each stream is 20 DN. The first meter is the check meter, the second one is the main custody transfer meter. With this approach the main meter, using the inlet piping of the full bore check meter and its own inlet piping of 10 DN, has a very long upstream pipe length of more than 30 DN in total.

This ensures that this meter has the most stable flow profile. The meters are from two vendors with different path configurations.

According to TR-G 18 the contractually accepted deviation between the meters is ±0.5%. As shown in Figure 5: Monthly difference USM1 vs. USM2 Vs.c. both metering streams are well within the limits, at ±0.15% to ±0.25%.



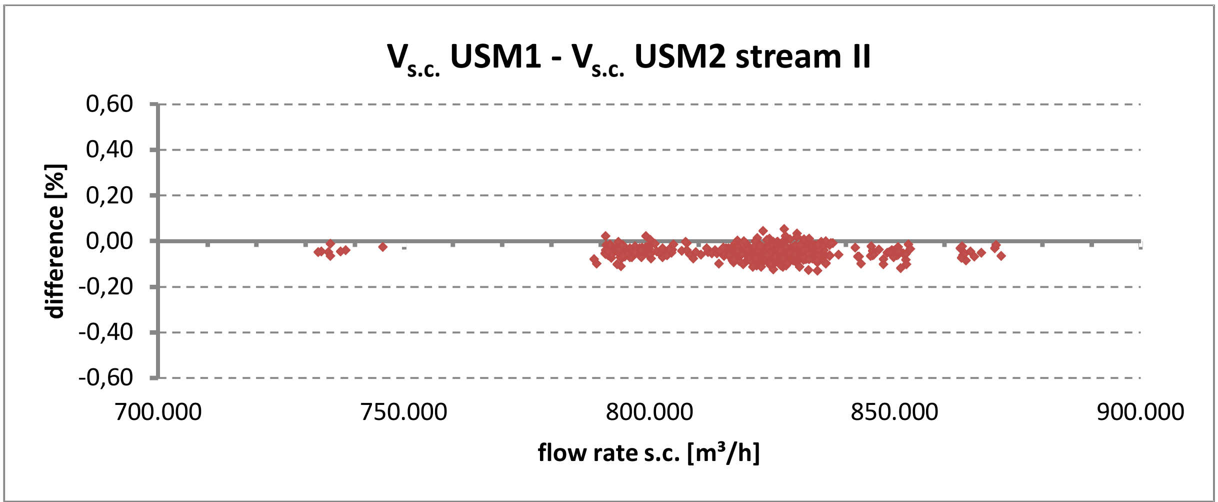


Figure 5: Monthly difference USM1 vs. USM2 $V_{s.c.}$

5.2 Metering Station B

A German power supplier operates a gas-fired city power station with a single 8-inch meter run featuring two ultrasonic meters installed in series. The first meter in the direction of flow direction is the check meter, and the second one the main meter. Both meters have an inlet piping of 10DN, including a flow conditioner in the middle of the inlet piping section. In this application the typical gas pressure is 45 bar and the gas temperature 8 °C in winter and 20 °C in summer.

Figure 6: Serial installation of two USMs, metering station B

One special feature of this application is that the check meter operates with a transducer frequency of 200 kHz in an eight-path layout and the main meter operates with a transducer frequency of 300 kHz in a four-path layout. Although both meters are from the same vendor, the meters can be considered to have a different sensitivity to installation effects due to the different path designs and the different operating frequencies.

Figure 7: Path layout of direct eight- and four-path meters

The comparision of the actual volume $V_{a.c.}$ is not applicable here due to the flow conditioner installed between the meters. This causes a pressure drop and a temperature difference between the meters. Therefore it is necessary to compare the meter readings based on the standardised volume $V_{s.c.}$ from the flow computers.

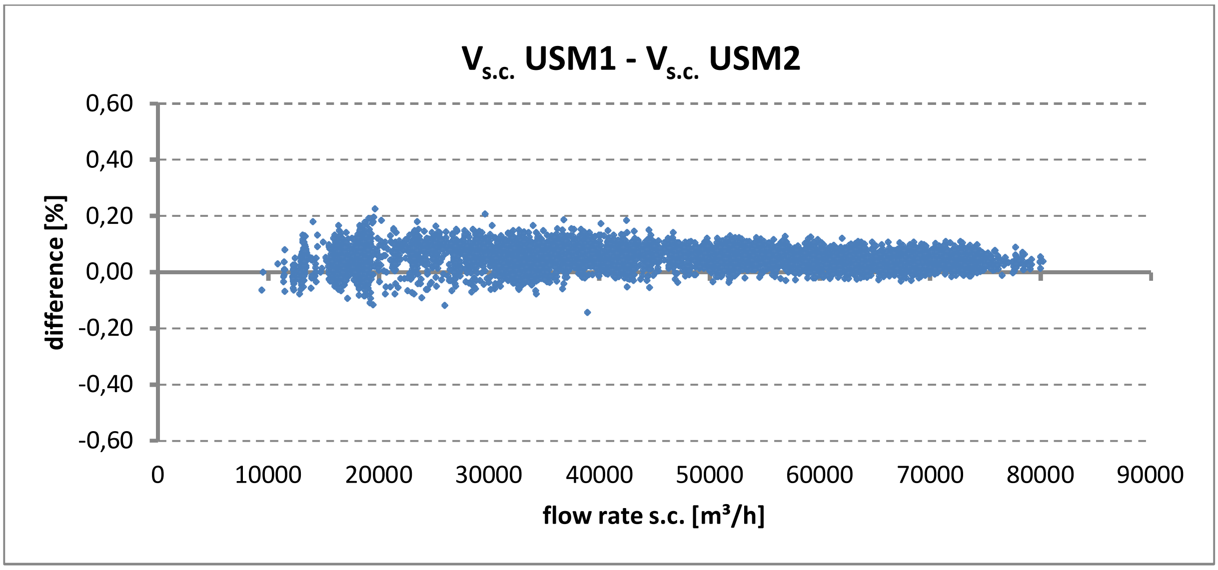


Figure 8: Hourly difference USM1 vs. USM2 $V_{s.c.}$ - values from one year in operation

The metering line is well within the acceptance limits of ±0.5%.

The required checks on speed of sound for the main and check meters also produce excellent results. All paths have insignificant deviations to the averaged measured speed of sound, see Figure 9.

	Comm. Finger Print (14.09.16) USM 1		Comm. Finger Print (14.09.16) USM 2		Verification 01.04.17 USM 1		Verification 01.04.17 USM 2		Verification 01.07.17 USM 1		Verification 01.07.17 USM 2	
Path 1-1	419,43	0,006%	419,57	0,002%	413,04	0,004%	413,04	0,003%	422,08	0,005%	421,99	0,006%
Path 1-2	419,43	0,006%	419,63	0,016%	413,03	0,002%	413,06	0,006%	422,06	0,000%	421,99	0,006%
Path 1-3	419,43	0,006%	419,59	0,007%	413,03	0,003%	413,06	0,006%	422,09	0,007%	421,99	0,006%
Path 1-4	419,46	0,012%	419,57	0,002%	413,05	0,007%	413,06	0,006%	422,09	0,007%	422,01	0,012%
Path 2-1	419,43	0,006%	-	-	413,06	0,009%	-	-	422,09	0,008%	-	-
Path 2-2	419,43	0,006%	-	-	413,03	0,002%	-	-	422,06	0,000%	-	-
Path 2-3	419,42	0,001%	-	-	413,05	0,007%	-	-	422,06	0,000%	-	-
Path 2-4	419,43	0,006%	-	-	413,05	0,007%	-	-	422,08	0,006%	-	-
Meter Average	**419,41**	0,006%	**419,56**	0,007%	**413,02**	0,005%	**413,03**	0,005%	**422,06**	0,004%	**421,96**	0,008%

Figure 9: Speed of Sound comparison

6. Challenges and Further Recommendations

The TR-G 18 is a legal basis to extend the re-verification period in excess of the nationally defined re-verification period in Germany. The two installations presented above are examples of the many installations today using ultrasonic gas flow meters installed in series. They show that it is very much achievable to operate the metering line synchronously within narrow deviation limits of less than ±0.5% in different installation setups. Based on the experience gained in this field over recent years it is very common to install such metering lines.

The additional available diagnostics features of the ultrasonic flow meters, such as path ratios, average gain control (AGC), signal-to-noise ratio (SNR), profile factor and symmetry are also an effective method to identify possible application issues which may not influence the deviation between the meters in service.

According to a third-party analysis of actual field robustness reported by DNV GL in June 2017[5], process-related metering errors can be linked to:

- Metering line design issues
- Liquids or contamination
- Build-ups on the pipe wall
- Blocked flow conditioners
- Noise
- Dynamic flow process due to pulsation

As an example, in terms of the metering line aging due to contamination over the years, both meters might be affected by this. There is a certain probability that if the measurement deviation of the metering line increases due to the contamination, this will not be detected during the online comparison. Since both meters react similarly to the contamination, the measurement difference between the two meters does not shift. But the measurement error of the metering run does shift.

Today's diagnostics functionalities overcome this issue. It is recommended not only to compare the meters' synchronization and speed of sound but also to look at further diagnostic values. Comparing a meter's fingerprint upon commissioning with actual data allows trends to be analyzed and thus signs of drifts and shifts to be identified.

Several tests and papers published over recent years have shown how to use diagnostics to detect process-related issues which may influence the measurement results.

A change of the profile factor and turbulence values indicate bottom fouling and changes in the wall roughness due to corrosion or contamination[6]. Combined changes to profile symmetry indicate blocked flow conditioners[7].

Noise has an impact on the signal to noise ratio (SNR), average gain control (AGC) and potentially also the acceptance rate of the ultrasonic signal.

One of the challenges is to make the diagnostics easier to interpret and understand in future. If meters installed in series do not show a shift in the deviation to each other but there is an issue in the process, it needs to be clear what the problem is.

Summary of recommendations:

- Integrate diagnostic capabilities of USM into meter run verification
- Make use of diagnostic trending to identify long-term impacts, such as corrosion or contamination
- In addition to a speed of sound comparison between measurement paths, compare to theoretical SOS values
- Consider the annual prolongation procedure for dry and clean gas applications
- Deviation limits on volume lower than ±0.5%, e.g. 0.3% require extreme accuracy in meter technology, referring to OIML class 0.5.
- Consider lower limits, e.g. ±0.3% if the in-service uncertainty is 1%

[5] cf. "Calibration and recalibration actions; a balancing act between costs and risks"; Henk Riezebos, Lennart van Luijk, Ronald ten Cate; FORCE Metering Workshop June 2017

[6] cf. "Considerations on the influence of deposits or changes in wall roughness on the validity of the calibration and long term accuracy of ultrasonic gas flow meters", Thomas Horst -SICK, Alexander Jakschik -SICK, Toralf Dietz-SICK, Henk Riezebos - KEMA; 29th NSFMW, 2011

[7] cf. "Ultrasonic meter condition based monitoring – a fully automated solution", George Kneisley – Transwestern Pipeline, John Lansing –SICK, Toralf Dietz – SICK; 27th NSFMW 2009

7. Conclusion

Application conditions in the oil and gas industry (especially in the transmission market) allow for longer re-verification periods today. Ultrasonic gas flow measurement has reached a very high level of quality and reliability. This is proven by many tests carried out by manufacturers, operators and third-party industry projects, and finally by re-verification data. Generally, the natural gas in the custody transfer gas market is clean and dry. Contamination or bottom fouling are very rare and typically do not affect precise measurement.

Learning from the past enables metering stations to be used which are optimized for very low uncertainty budgets related to station design. And diagnostics of ultrasonic flow meters support meter and process monitoring to ensure that measurements are stable.

Technical recommendations such as TR-G 18, in line with national directives, allow the re-verification period to be extended, which helps to reduce operational expenses. The guideline is certainly always a compromise between operational expenditures caused by re-verification and financial exposure due to measurement uncertainties.

In the German gas transmission market it is very common to utilize ultrasonic gas flow meters installed in series according to the TR-G 18 approach today. A regular monitoring and verification of the metering lines is the key to benefit from the regulative frame work given by the PTB. Examples from two metering stations in Germany with different designs have been given in this paper and show the validity of the concept. For further acceptance it is mandatory to gather more field data and re-verification results from metering lines which need observation. Such cases need to be evaluated and published to the industry to further leverage the concept described in TR-G 18. Operators using such designs today, rely on this concept and save operational costs by the annual extension of the verification interval.

Literature references

[1] "Verordnung über das Inverkehrbringen und die Bereitstellung von Messgeräten auf dem Markt sowie über ihre Verwendung und Eichung (Mess- und Eichverordnung - MessEV)"; MessEV; 11.12.2014

[2] "Änderung der Eichordnung – Allgemeine Vorschriften (AO-AV) Anhang B (Besondere Gültigkeitsdauer der Eichung) Nr. 7.1 bis 7.5"

[3] "Messgeräte für Gas TR-G 18"; PTB; https://www.ptb.de; 2017

[4] "Measuring Instruments Directive (MID)"; http://ec.europa.eu/growth/single-market/goods/building-blocks/legal-metrology/measuring-instruments/; 2017

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[6] "Considerations on the influence of deposits or changes in wall roughness on the validity of the calibration and long term accuracy of ultrasonic gas flow meters", Thomas Horst -SICK, Alexander Jakschik -SICK, Toralf Dietz-SICK, Henk Riezebos - KEMA; 29th NSFMW, 2011

[7] "Ultrasonic meter condition based monitoring – a fully automated solution", George Kneisley – Transwestern Pipeline, John Lansing –SICK, Toralf Dietz – SICK; 27th NSFMW 2009