Important considerations regarding calibration of ultrasonic gas flow meters

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Introduction

Multipath ultrasonic gas flow meters are normally flow calibrated at an accredited flow laboratory before installation in order to verify the flow meter's performance and to correct for flow meter offset. The common practice is to install gas flow meters without in-situ calibration arrangement. Many of these flow meters are never recalibrated. It is therefore important to ensure that the flow meters are calibrated properly with the highest degree of confidence to the involved parties. This article will highlight some important aspects regarding preparations and execution of gas USM flow calibration. Some improvement issues are also discussed.

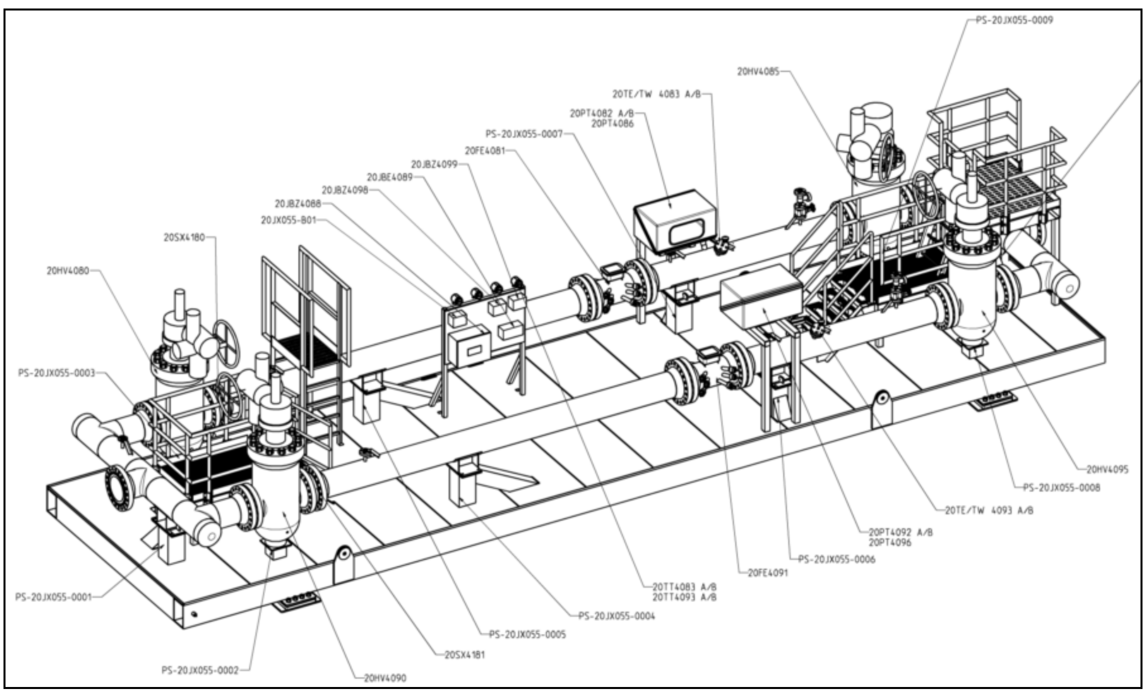

Figure 1. Typical ultrasonic gas flow meter installation

Preparations

The upstream pipe which will be installed with the flow meter, or an identical pipe spool with the same length and inner diameter, must be used for the flow calibration in order to provide similar flow profile during calibration as will be expected at the final installation site. If a flow conditioner is part of the final installation, this flow conditioner must also be used during calibration.

The calibration laboratories have limited test runs available with flange type and rating designed for the maximum pressure at the facility. Adapter spools are therefore often required to match the line size and flange type of the flow meter.

The calibration laboratories use their own pressure and temperature transmitters in order to conform to their accredited procedures. The flow meter or the adjacent pipe spools of the same line size should have a pressure tapping to allow for connection of the laboratory's pressure sensor. This is particularly important if the laboratory lines size is different than the flow meter size. For instance, if a 6-inch flow meter is installed in a 12-inch test pipe, the pressure in the 6-inch flow meter will be lower than the pressure in the 12-inch pipe due to higher gas velocity in the flow meter.

It is also important to supply the bolts and gaskets required for the flow meter, upstream pipe and adapter spools.

Most calibration laboratories will require a pressure test certificate before installing the flow meter and test spools into their laboratory.

Choice of calibration laboratory

The choice of calibration laboratory will be determined by the flow capacity and the geographical location as most customers will select the nearest laboratory that complies with the maximum and minimum calibration flow rates. It is worth checking that the laboratory is accredited to ISO 17025 for the chosen flow range. Although most laboratories are accredited for the complete flow range that is offered, this may not always be the case. Also, the type of test gas as well as pressure and temperature levels offered varies between the different calibration laboratories. An overview of the most commonly used flow calibration laboratories for gas is listed below.

Name	Location	Gas type	Range (m3/hr)	Pressure (barg)	Temperature (°C)	Uncertainty (k=2)
Pigsar	Dorsten, Germany	Natural Gas	8 – 6500	14 – 50	N/A	0.16%
http://www.open-grid-europe.com/cps/rde/xchg/SID-F2210DCD-89EB588A/open-grid-europe-internet/hs.xsl/2788.htm						
Force Technology	Vejen, Denmark	Natural Gas	8 – 10000	0 – 50	15 – 25	0.18 – 0.30%
http://www.forcetechnology.com/NR/rdonlyres/64661935-40D6-4E1A-9886-4E0BFB69805F/3713/24846en.pdf						
GL Noble Denton	Durham, England	Natural Gas	20 – 19500	35 – 55	5 – 15	0.19 – 0.24%
http://www.gl-nobledenton.com/en/consulting/FlowMeterCalibration.php						

NMi Euroloop	Rotterdam, The Netherlands	Natural Gas	5 – 30000	0 – 60	N/A	0.15%
http://www.nmi.nl/metrology/euroloop/gas/specifications						
CEESI	Iowa, USA	Natural Gas	10 – 34000	70	N/A	0.23%
http://www.ceesi.com/FlowMeterCalibrationCapabilities.aspx						
TransCanada Calibrations	Manitoba, Canada	Natural Gas	30 – 55000	60 – 70	N/A	0.19%
http://www.tccalibrations.com/						

Table 1. Overview of gas flow calibration laboratories.

Check points during flow calibration

At the flow calibration laboratory there are some important issues to be addressed. I have listed them below in a chronological sequence.

Before calibration start

- Agree on the calibration procedure and acceptance requirements. Supplier, client and laboratory personnel should meet to go through the procedure with respect to flow range, number of repeats, verification points and other project specific requirement.

- Inspect the flow meter installation. Check that the flow conditioner and upstream pipe is installed correctly with respect to flow direction and orientation. It is a good practice to take pictures, if allowed, to document the physical installation arrangement.

- Check that the same output signal is used during calibration as will be used in the final installation for traceability purpose. It is recommended to use pulse output since this is a simple and straight forward representation of the flow rate.

- Check the parameter setup of the flow meter to be calibrated.

    - Check that the nominal K-factor (pulses/m^3) in the flow meter is used by the flow laboratory.

    - Check that inner diameter, path lengths and transducer parameters are entered in accordance with supplier certificates.

    - Check that correct linear thermal expansion coefficient and modulus of elasticity (Young's modulus) is entered into the flow meter for correct temperature and pressure diameter compensation. Typical values for linear thermal expansion coefficient are 1.10E-05 m/m/°C for carbon steel , 1.60 E-05 m/m/°C for SS316 grade steel and 1.30E-05 m/m/°C for duplex material. Typical value for modulus of elasticity is 2.0E+06 bar for carbon and stainless steel.

- o Check that the process pressure and temperature is entered manually into the flow meter for correct diameter compensation.
- o Print the parameter setup report to document the flow meter configuration during flow calibration.

During calibration

- Check that the process conditions such as pressure, temperature and flow rate are stable during the flow calibration. Drifting process conditions will most likely affect the flow measurement repeatability.
- Check that there are no alarms generated in the flow meter by its internal diagnostics system.
- Check for normal values of automatic gain, percentage of accepted ultrasonic pulses, path velocities and velocity of sound (VOS) on each transducer pair. The spread in VOS should exceed 0.5 m/s between all transducer pairs during normal flow.

After calibration

- Check the repeatability and linearity towards the calibration procedure.
- If the flow correction shall be entered into the flow meter, check that correct parameters are entered. The correction is entered either as flow weighted mean average, a polynomial or as a flow rate/correction factor matrix with interpolated correction. A verification point may be repeated after entering the flow meter correction in order to document correct entering of the flow correction.
- Print the parameter setup report to document the flow meter configuration after flow calibration.

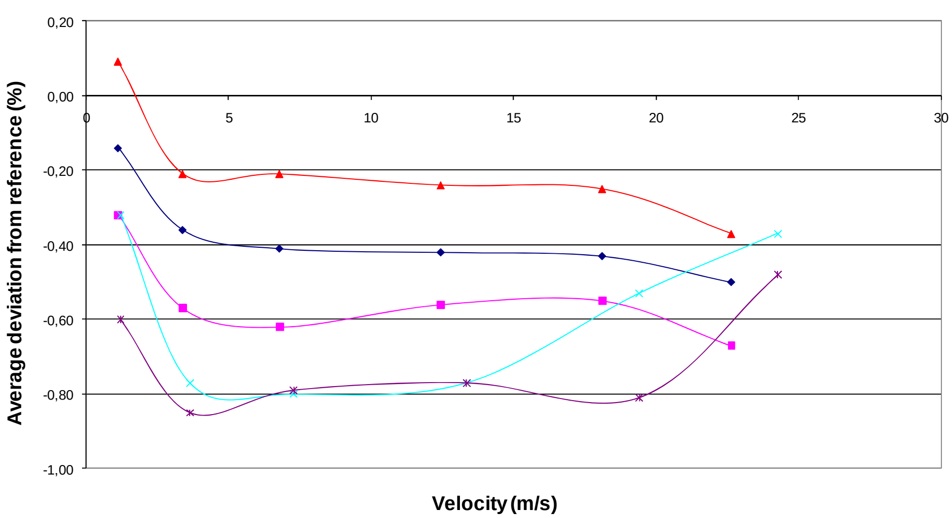

Figure 2. Typical linearity plots for multipath ultrasonic gas flow meters

Re-calibration or condition monitoring

Some authorities or operators have requirement for recalibration of fiscal multipath ultrasonic flow meter like. Fiscal ultrasonic gas flow meters on the UK side are typically flow calibration periodically with a maximum interval of five years. On the Norwegian sector the operators will normally monitor condition parameters to determine if flow calibration is required. The common condition parameters are Automatic Gain Control (AGC), acoustic signal acceptance, velocity profile and velocity of sound.

- The AGC is measured per transducer and is dependent on the gas density. This means that as long as the gas density or gas pressure remains stable, the AGC value for each transducer should remain unchanged.

- The acoustic signal acceptance is typically displayed as a percentage value indicating how large portion of the acoustic signals received by each transducer are recognized by the signal processing unit in the flow meter. A drop in the acceptance value can indicate a deteriorated transducer.

- The normalized velocity ratio (velocity measured by each path compared to the overall flow velocity) is an indication of the gas flow profile in the flow meter. The flow profile will remain fixed for a large flow range. A major change in the indicated velocity profile indicates a problem with one transducer pair.

- The velocity of sound (VOS) is the most important parameter to be monitored. The VOS is measured by each path. Regardless of changes in the process conditions, all paths should measure the same VOS as long as there is flow through the flow meter. Maximum difference between the highest and lowest VOS reading will normally stay with 0.5 m/s. The average VOS (across all paths) should be compared to AGA-10 calculated VOS from online gas chromatography. Drifting discrepancy of measured (USM) VOS compared to calculated (GC) VOS indicates a drift in either the USM or the gas chromatograph.

The condition monitoring opportunities in the multipath ultrasonic gas flow meters should be used actively to evaluate the need for recalibration.

Current path values

	Flow velocity	VOS	Turbulence	S/N Raw	S/N Used	Signals		Gain	
Path	*m/s*	*m/s*	*%*	*dB*	*dB*	*%*		*-*	
1	0.000	398.40	0.0	28	52	99	99	1000	1000
2	0.000	398.40	0.0	28	52	99	99	1000	1000
3	0.000	398.75	0.0	28	52	99	99	1000	1000
4	0.000	398.75	0.0	28	52	99	99	1000	1000
5	0.000	398.75	0.0	28	52	99	99	1000	1000
6	0.000	398.40	0.0	28	52	99	99	1000	1000

Figure 3. Typical diagnostics data for multipath ultrasonic gas flow meters

Suggestions for improvement

Better availability

A flow calibration job must be ordered typically several months in advance. The flow calibration laboratories are staying busy. More laboratories would increase the availability for flow calibration as the number of flow meters in operation continuous to increase.

Lower uncertainty

The uncertainty of the flow measurement at the calibration laboratories range from 0.16 to 0.30%. The USM manufacturers claim uncertainties for their multipath gas flow meters in some cases less than 0.50% as delivered from the factory. The resulting linearity and repeatability values for a meter under test is therefore largely affected by the uncertainty of the calibration laboratory. The uncertainty of the laboratories should be improved in order to maintain lower uncertainty than the test meters by a considerable margin. For calibration of other instruments the reference instrument typically is five or even ten times more accurate than the test instrument. For USM flow calibration the reference instrumentation is only two or three times better.

Higher flow capacity

A simple calculation of the flow meter capacities is shown in the table below assuming nominal diameter and maximum 25 m/s gas velocity.

Size (Inches)	ID (mm)	Vel (m/s)	Flow rate (m3/h)
4	100	30	848
6	150	30	1909
8	200	30	3393
12	300	30	7634
16	400	25	11310
20	500	25	17671
24	600	25	25447
30	750	25	39761
36	900	25	57256
42	1050	25	77931

Table 2. Typical USM maximum range for different size of meters

We see from the table that for large flow meters of size 24-inch and higher the number of test sites is very limited. There are two test sites in North America that can handle the full flow range. There is a need for calibration laboratories within Europe that can flow calibrate these size meters.

Higher pressure and temperature

The flow calibration laboratories operate on gas pressures up to 50 barg, some up to 70 barg. Gas temperatures are typically in the range of 5 to 30 °C at the laboratories.

The ultrasonic transit time measurements in ultrasonic gas flow meters must be corrected for delays in the transducers. The transducer delay is dependent on pressure and temperature. The extent of transducer delay variation over pressure and temperature depends on the design of the ultrasonic transducer, some factors being stability of piezo-electric sensor, mounting of sensor and type of matching layer. The manufacturers of the ultrasonic gas flow meters use different methods for determining the transducer delay, and for the pressure and temperature compensation of the transducer delay, either through factory calibrations or through empirical estimates.

Pressure and temperature will also affect the inner diameter of the flow meter. Since ultrasonic flow meters measure the flow velocity, volumetric flow rate is proportional to the square of the inner diameter. The diameter correction is done either inside the flow meter or in the system flow computer, normally by standard pipe expansion algorithm which may not be fully applicable for the flow meter body.

Many ultrasonic gas flow meters in pipeline applications operate at pressures between 100 and 200 barg. Operating temperature between 50 and 100 °C are not uncommon. An added uncertainty for installation effect must be applied if these flow meters are calibrated at considerably lower pressures and temperatures. The added uncertainty for installation effect is typically estimated to 0.2 to 0.5% in uncertainty budgets for metering systems. If the flow meters are calibrated at pressures and temperatures close to final operating conditions, the contribution from installation effects can be reduced.