

A Method for Maintaining Accuracy of Ultrasonic Gas Flow Meters Calibrated on Air at Atmospheric Pressure when Measuring Natural Gas at High Pressure

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Abstract

With the increase in the requirements for the accuracy of measurement in the commercial accounting of natural gas, the issue of initial calibration and periodic verification of measuring instruments in conditions as close as possible to actual working conditions is relevant and commonly discussed among professionals. This issue also applies to ultrasonic gas meters. Despite the general tendency to calibrate (verify) ultrasonic gas meters at operating conditions, this requirement is not always appropriate. First of all, this is due to the high cost of calibration services and the insufficiently developed network of accredited calibration laboratories. The issue of determining the rules and criteria for justifying the need to calibrate ultrasonic gas meters at operating conditions remains extremely concurrent.

1. Statement of the problem

The major issues of metrological support of ultrasonic gas meters are the following:

1. Adequacy of calibration and verification of ultrasonic gas meters using "air" at atmospheric pressure as medium as compared to the use of "natural gas" at working pressure as medium for calibration.

The requirement of meters calibration and verification in conditions that are as close as possible to working ones is necessary, but not always optimal, because of the high technical, time and financial expenditures required to carry out this calibration (verification). Therefore, an evaluation of the results of comparing the calibration characteristics of meters obtained in air at atmospheric pressure and on natural gas at high pressure is a crucial task.

2. Insufficiently developed metrology infrastructure - currently there is just a small number of calibration labs working on natural gas at high pressure.

3. The normative base that regulates the calibration of meters in different environments and pressures is not developed - currently there are no compulsory normative documents regulating

compulsory testing on the working medium, as well as documents defining the criteria for selecting the medium and pressure for verification of ultrasonic gas meters.

2. Analysis of recent researches and publication

Analysis of the main international and state regulatory documents, as well as industry standards, demonstrates the lack of a unified approach to the requirements for determining the working environment and pressure when calibrating and periodical verification of ultrasonic gas meters [1-4].

The requirements for testing, calibration and verification of ultrasonic meters, depending on the class of their accuracy and the parameters of the working environment, are either contradictory or recommendatory in nature.

For example, paragraph 13.1.3 of OIML R 137 1&2 specifies the necessity to test the meters under the conditions closest to the operating ones. However, there are no specific criteria for choosing a decision on the verification conditions. Moreover, it is possible to carry out verification on the type of gas that is different from the operating one, according to the decision of the authorized bodies, and this can add the subjective human factor.

Statistical analysis of the existing regulatory documents (Table 1) shows, that meters of class 0.5 and 1.0 having maximum permissible error in the range of $\pm 0,5-1,0\%$ for flow range $Q_t < Q < Q_{max}$ are most common and are used in international classifications.

Table 1 — Classification of gas meters in accordance value of with maximum permissible error (MPE)

Class	MPE $Q_{min} < Q < Q_t$, %	MPE $Q_t < Q < Q_{max}$ %	AGA Report №9	ISO 170891:2010	OIML R 137-1&2	Directive 2004/22/EC (MID)	RGazprom 5.13 - 2010
0,3	$\pm 0,6$	$\pm 0,3$					X
0,5	$\pm 1,0$	$\pm 0,5$			X		X
0,7	$\pm 1,0$	$\pm 0,7$					X
	$\pm 1,4 > 12''$	$\pm 0,7 > 12''$	X				X
	$\pm 1,4 > 12''$; $\pm 1,4 < 12''$	$\pm 0,7 > 12''$; $\pm 1,0 < 12''$		X			X
1,0	$\pm 2,0$	$\pm 1,0$			X	X	X
	$\pm 1,4 < 12''$	$\pm 1,0 < 12''$	X				X
1,5	$\pm 3,0$	$\pm 1,5$			X	X	
	$\pm 2,0 > 12''$; $\pm 2,0 < 12''$	$\pm 1,0 > 12''$; $\pm 1,5 < 12''$		X			

According to regional regulatory requirements, these classes of meters are the basic ones for commercial accounting of natural gas, and calibration (verification) on natural gas at operating pressure is objectively related either to the limitation of technical capabilities or to high time and financial expenses.

Paramount issues are the following:

- for meters of what accuracy class it is required to perform calibration on natural gas, and for which it is not compulsory?
- whether it is possible to confirm the metrological parameters of ultrasonic gas meters of class 0.5; 0.7 and 1.0 in the range $Q_t < Q < Q_{max}$ under operating conditions after calibrating them in air at atmospheric pressure?

For example, the official calibration schemes approved in the territory of the CIS countries do not currently require verification (calibration) of ultrasonic meters on natural gas and working pressure [5,6]. The specified official reference to the verification of ultrasonic gas meters on natural gas is described in the corporate Recommendations of the "OAO Gazprom" Organization that regulate the calibration of high-precision ultrasonic meters with MPE no more than

0.35% with "natural gas" as verification medium and the pressure closest to the working one, and verification of the meters of class 1,0 - in air at atmospheric pressure [7].

European regulations allow the meter to be calibrated at an operating pressure of up to 6 bar in air at atmospheric pressure. At the same time, meters designed for operation at pressures above 6 bar must be calibrated in conditions as close as possible to working ones [8].

The question of the possibility of replacing the verification conditions and the criteria for making a decision remains open.

3. The aim of the research

As a rule, meters are calibrated and calibrated on calibration stands using air as measured medium at a pressure close to atmospheric pressure, while later they are used to account for natural gas at a higher pressure. As a result, the question arises of the correctness of such metrological procedures from the point of view of the actual error of the meter at operating conditions.

Until recently, there was little or no detailed research into the discrepancies that arise when verifying counters or gas flow meters using air, which is a medium that replaces the working environment of such devices-natural gas.

This is due in particular to the following:

- a small number of verification stands operating on natural gas at high pressures;
- a poorly developed regulatory framework that does not clearly define the criterion - which meters need to be calibrated on air at atmospheric pressure and which ones should be calibrated on medium and pressure corresponding to the operating conditions.
- the use of air instead of natural gas simplifies the design of test facilities, reduces their cost and significantly reduces the safety requirements for their operation.

It is believed that such a replacement is not only permissible, but also expedient. In support of this, the following arguments are presented:

- when checking, it is not necessary to determine the density of the working medium;
- full safety of verification process is guaranteed;
- consistent repeatability of verification results is ensured, since gas meters calibrated in air at zero overpressure and operating on gas at completely different pressures initially have a stable

conversion factor (a constant ratio of the output signal to the flow of air or gas passing through the instrument). This ensures reliable convergence of readings for different media and operating conditions. Otherwise, since in the gas measurement unit, in addition to the volumetric flow, it is still necessary to measure the temperature and pressure of the gas, even in the absence of the necessary stability of the conversion coefficient, it is always possible for the device to linearize its static characteristic during its calibration. And when moving to real operating conditions, also make the appropriate adjustments, calculating the Reynolds number (Re) for each measurement case. Moreover, modern microelectronics can solve even more complex problems at relatively low costs.

Though the above arguments sound convincing, there are restrictions which apply. The problem of repeatability of the results discussed above can be solved in principle, but it is necessary to fully formulate the applicable conditions, and this has not been feasible so far. The point is that when the gas flows through the pipeline, and especially when it is expanded or compressed (as happens, for example, when the pipeline has bends or any obstacles in the flow and the medium goes around the flow), complex aerodynamic and thermodynamic processes take place. Accordingly, the flow depends not only on the value of Reynolds number Re , but also on the values of other aerodynamic and thermodynamic coefficients, in particular, the values of Strouhal number (St), Nusselt number (Nu) and Froude number (Fr). And it has generally not been possible to carry out flow correction taking into account these values, because, firstly, there is insufficient experimental data, and secondly, in order to determine these values, we need at least continuous information on the composition of the gas, which is absent in most of the cases of installation of gas meters.

Thus, the feasibility of replacing natural gas with air for calibration can only be judged by analyzing in detail and confirming in practice the effect of such a replacement on the course of the processes that occur when verifying meters with the help of test rigs, and also during their operation in real conditions.

4. The main material

There are quite a large number of sources regulating the requirements for calibration of turbine and rotary gas meters, as well as data on comparative tests of these meters under different

conditions [9-12]. Manufacturers of turbine and rotary gas meters, as a rule, measure meters both in air at atmospheric pressure and on natural gas for various pressures. The results of the calibration show the deviations of the characteristics of these meters for different values of the pressures of the medium being measured and the type of this medium.

At present, there is little information available on similar tests of ultrasonic meters. This information is either kept secret by manufacturers, or it is not available at all.

In order to determine the feasibility of conducting a primary (periodic) calibration at operating conditions of USGM of class 0.5; 0.7 and 1.0, an experimental study of two-channel and four-channel ultrasonic gas meters Energoflow GFE was carried out within the framework of the test program for compliance with the requirements and recommendations of the Directive 2014/32 / EC (MID) and OIML R 137-1 & 2.

When designing the instruments, an algorithm was used that made it possible to implement a mathematical model of calculations that maximally takes into account the dynamic processes in the measured flow. This solution allows calibrating the meters on air at atmospheric pressure, after which, by entering into the electronic unit the parameters of the working medium that correspond to the actual operating conditions of the meter (natural gas parameters, operating temperature and pressure ranges), keeps the measurement error in permissible range at operating conditions for various media and at different pressures.

The results of consequent verification of meters on natural gas at pressure of 4.0; 20.0 and 30.0 bar in the FORCE Technology laboratory (Denmark) and testing facilities of RMA (Germany) laboratory after initial calibration in air at atmospheric pressure demonstrated that these modifications of the meters confirm to the corresponding accuracy class of 0.5; 0.7 and 1.0 in the range $Q_t < Q < Q_{max}$ according to OIML R 137-1 & 2 and MID 2014/32 / EU, respectively (Figures 1, 2).

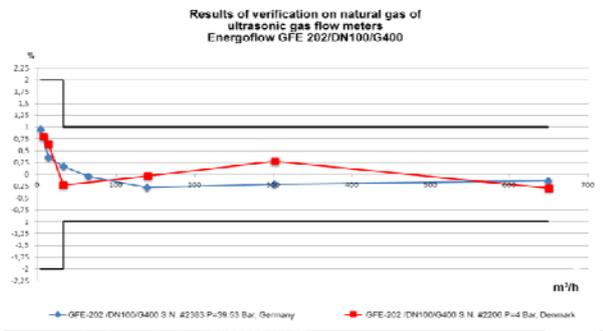


Figure 1 – Energoflow GFE 202 error curve

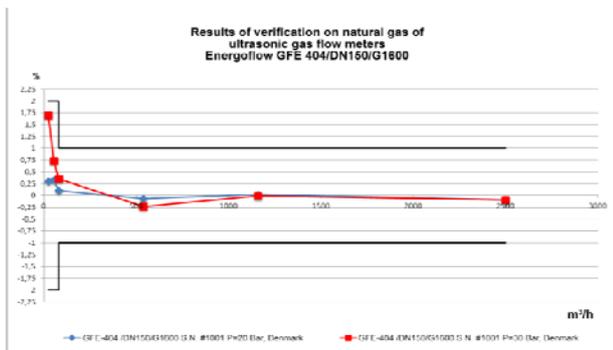


Figure 2 – Energoflow GFE 404 error curve

Particular attention should be paid to the Energoflow GFE 202 and Energoflow GFE 404 testing carried out to assess their conformity with the requirements of the MID 2014/32/EU Directive. These tests were conducted by representatives of PTB (Germany). The main types of tests are confirmation of the metrological characteristics on natural gas and at high pressure in conditions of strong disturbance of the flow caused by local resistances of the following configurations: "two bends in different planes", "two bends in different planes with the addition of a half pipe area plate (half-moon opening)" at different lengths of straight pipe runs and meter orientations. These tests were carried out at the testing facilities of RMA (Germany) laboratory.

Tests results (Figs. 3-7) confirmed the Energoflow GFE 202 and Energoflow GFE 404 compliance with the requirements of OIML R 137-1 & 2 and MID 2014/32 / EU.



Figure 3 - Test results of the Energoflow GFE 202 at RMA calibration facilities (standard conditions, air, natural gas)



Figure 4 - Test results of the Energoflow GFE 202 at RMA calibration facilities (two bends in different planes, air, natural gas)

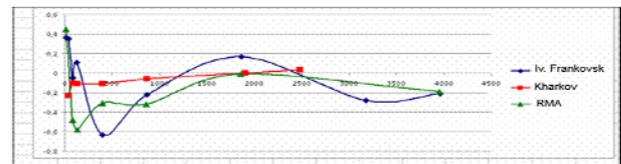


Figure 5 - Comparative results of Energoflow GFE 202 tests on different mediums and at various pressures

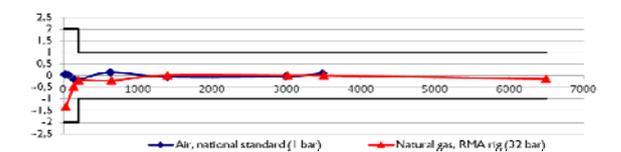
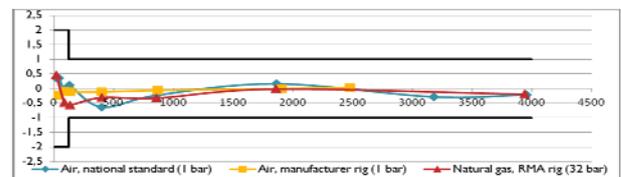


Figure 6 (a, b) - Test results of Energoflow GFE 404 at RMA calibration facilities (standard conditions, air, natural gas)

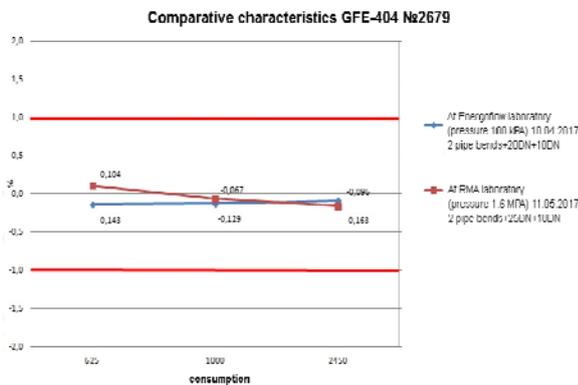


Figure 7 – Test results of Energoflow GFE 404 at RMA calibration facilities (two bends in different planes + half-moon opening, air, natural gas)

5. Conclusions

Considering the above, during the tests, Energoflow AG developed and checked an algorithm that enables to implement the mathematical model of calculations, maximally takes into account the dynamic processes in the flow to be measured. This solution allows for calibrating the meters on air at atmospheric pressure, and then, by entering in the electronics unit the parameters of the operating medium, which correspond to the real conditions of meter operation (parameters of natural gas, operating temperature and pressure ranges), to maintain the permissible values of errors in working conditions on different mediums and at various pressures.

1. Ultrasonic gas meters Energoflow GFE 202 and Energoflow GFE 404 showed good stable results in all types of tests and for different working mediums.

2. Despite the general tendency for calibration (verification) of ultrasonic gas meters under working conditions, this requirement is not always appropriate. Due to a significant reduction in the cost of calibration and associated transport costs during periodic maintenance, the proposed algorithm enables to expand the possibilities of using ultrasonic gas meters after calibration on air for natural gas measurement without additional calibration at process pressure on natural gas.

3. The obtained results open prospects for further research and improvement of technologies of ultrasonic gas meters in order to accumulate statistics of test results and the possibility of approving the described methodology at the regulatory level.

4. As a result of tests carried out jointly with PTB, MID certificate No. DE-16-MI002-PTB008, Revision 3 for Energoflow GFE202 and Energoflow GFE404 was obtained and report of class 0.5 according to OIML R137 1&2, section 5.3.2. for Energoflow GFE404 was issued.

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