New technology of natural gas flow rate measurement based on ultrasonic method

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1. ABSTRACT

Ultrasonic technologies application for flow rate measurement of natural gas during its production and transport are the subject of growing interest for the last 10-12 years. Ultrasonic flowmetery is considered to be reliable and competitive alternative today to the existing measurement means, such as turbine and orifice plate flowmeters. This great interest is caused by such ultrasonic technologies advantages as:

- noninvasive measurement (without flow disturbance).
- absence of pressure losses.
- wide dynamic range (40:1 and more).
- bidirectional operational regime (less pipelines are needed).
- requirement of short straight pipeline sections (usually 10 diameters before transducers and 5 after).
- possibility of low dependence from calibration.

The advantages of developed by "Vympel" company ultrasonic flowmeter are proposed in this paper. The results of tests and operation of flowmeters "HyperFlow-US" are represented. The prospects of their industrial implementation on pipelines of diameters from 100 to 1600 mm are analyzed.

C O N T E N T S

2. BODY OF PAPER

This work is devoted to the new measurement technology that was developed as a result of prolonged studies of ultrasonic method of gas flow rate measurement. The backbone of this technology is impulse-time principle of flow rate measurement. Gas flow velocity according to this principle is determined by transit time measurement of high-frequency sonic impulse which is extending across the pipe at angle to the axis along and against the gas flow. The difference between the transit time along/against the flow is proportional to gas flow average velocity along the acoustic way. During the development process the problem of minimizing the deficiencies of ultrasonic flowmeters, made according to classical scheme, was posed.

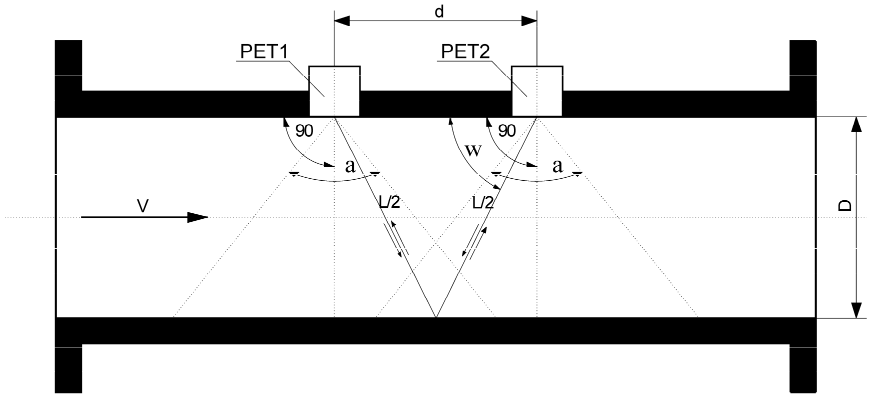
As is known, ultrasonic transducers are installed at angle to the pipeline surface in all modern flowmeters where this method is realized. That is why there are either cavities in the sites of transducers installation, or the latter protrude into the pipeline interior disturbing the flowing medium. In both cases the transducer radiating surface fouls by dust and mud that flows with gas. As a result of it transducers characteristics degrade or get out of order. Besides, installation of device transducers to the pipeline at angles to the axis is possible only in plant conditions.

The distinctive features of proposed method are based on the application of wide-aperture fitted piezoelectric transducers, installed perpendicularly to the gas pipeline axis, which posess several advantages:

- considerable reduction of installation labour content and possibility of flowmeter installation to the running pipeline under operating pressure;
- absence of cavities due to combination of transducers external radiating surface with the internal surface of measuring pipeline;

- possibility of receiving and processing signals by several acoustic channels per measurement cycle by one transducers pair operating alternately in “reception-transfer” regime.

Average gas velocity in the pipeline is calculated through the average velocities of several different acoustic rays. The algorithm of signals processing takes into account both, the rays passed through the axis of the measuring pipeline section, and rays passed along the chords after multiple reflection.



$$V = L^2 \cdot \frac{\Delta t}{2d} \cdot t_{12} \cdot t_{21},$$

$$V_a = k \cdot V$$

$$Q_p = \pi \cdot D^2 \cdot k \cdot \frac{V_a}{4}$$

Figure 1. Scheme of the proposed ultrasonic method of gas flow rate measurement:

PET 1, 2 - piezoelectric transducers; D - diameter of measuring pipeflange; L - length of acoustic way; d - distance between the active centers of ultrasonic transducers; w- slope angle of the acoustic way to the line of pipeline axis; V - average flow velocity along the acoustic way; ɑ - the aperture angle of piezoelectric transducers directional pattern.

Several models of transducers were developed. They include:

- the stainless steel body with sleeve rings;
- the piezoceramic emitter of membrane type with the radial oscillation mode and radiation angle of 75°;
- the dampfer which suppresses back radiation of acoustic wave into the pipeline wall.

Figure 2. Piezoelectric transducers of flowmeter.

Compensating channels are inbuilt in transducer for pressure equation in emitter internal space. Transducer construction is leak-free for low pressures. The special construction of leak-free transducer with damper is developed for the aggressive media including, in particular, torch gases. The damper has external covering from thin-walled metal tube.

In addition to advantages, application of transducer with the wide radiation pattern created some technical difficulties, caused by limitation of signal duration. This problem is solved in developed device via the synthesis of special excitation signal, which suppresses free fluctuations of receiver without limitation of its merit factor. For this purpose transducers are periodically tested, and their reaction is recorded. Then the synthesis of excitation signal is produced.

After that the model of expected signal of receiver is built on the known transducers parameters and excitation signal.This model is used for real signal processing. The received signal undergoes phase correction to consider the effects, which appear during signal reflection from pipeline walls.

The described procedure is produced with specific periodicity, because parameters of transducer depend on ambient conditions. Propagation time measurement of signal is made as follows. The synthesized excitation signal is transmitted to one of the transducers. The signal of the second transducer is recorded.

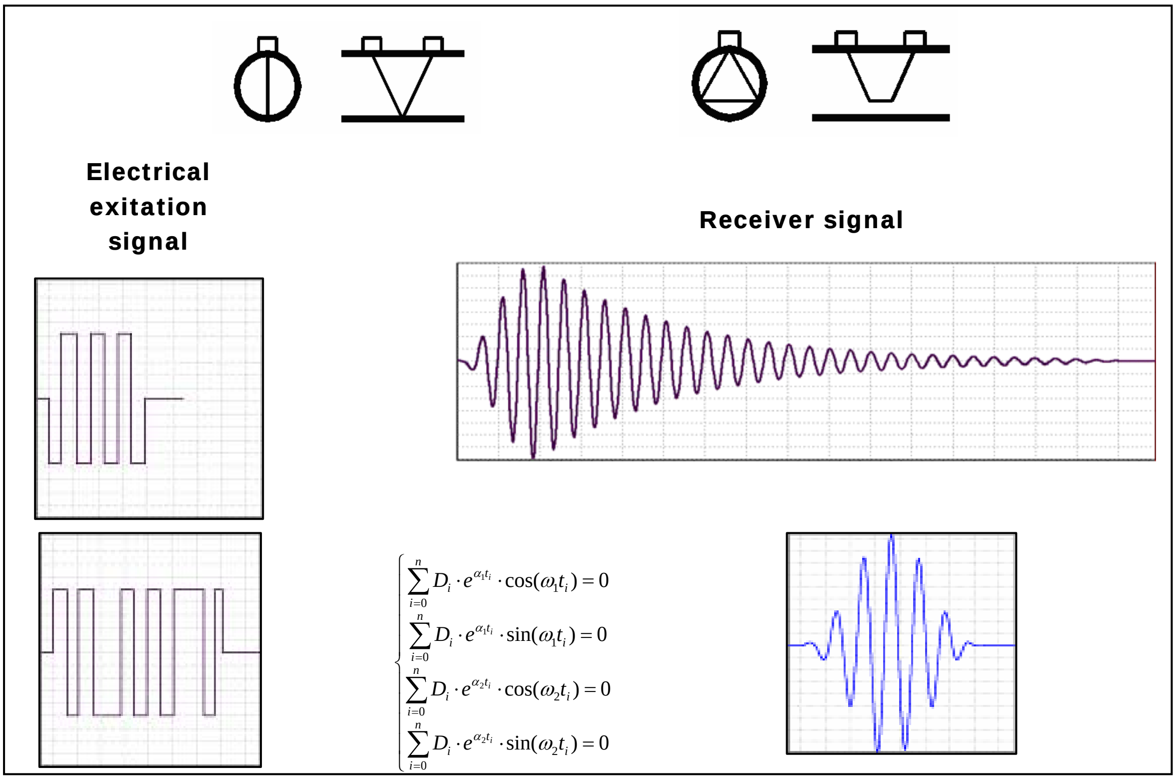


Figure 3. Formation of acoustic signal.

After this, the correlation function is calculated between accepted signal and model of the expected signal. The time of maximum of correlation function is equal to the time of signal propagation. Herewith its own maximum is used for different ways of acoustic wave propagation. The process repeats after the time interval, sufficient for damping of acoustic oscillations in the measured medium, but with interchange of transducers functions. The former transmitter becomes receiver, while the former receiver becomes transmitter.

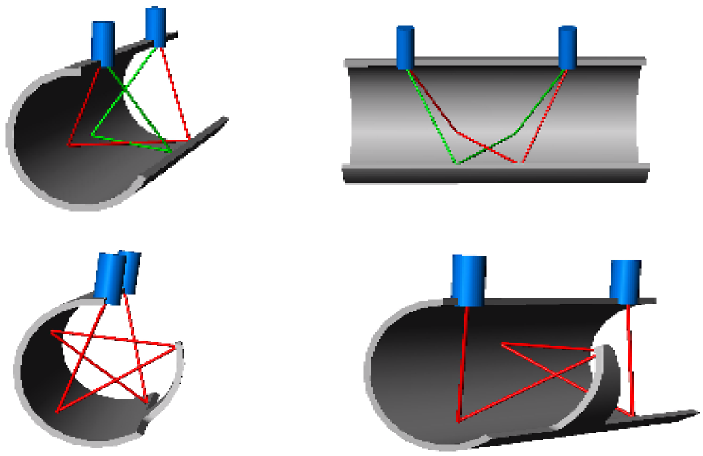


Figure 4. Variants of passing ultrasonic signals between transducers.

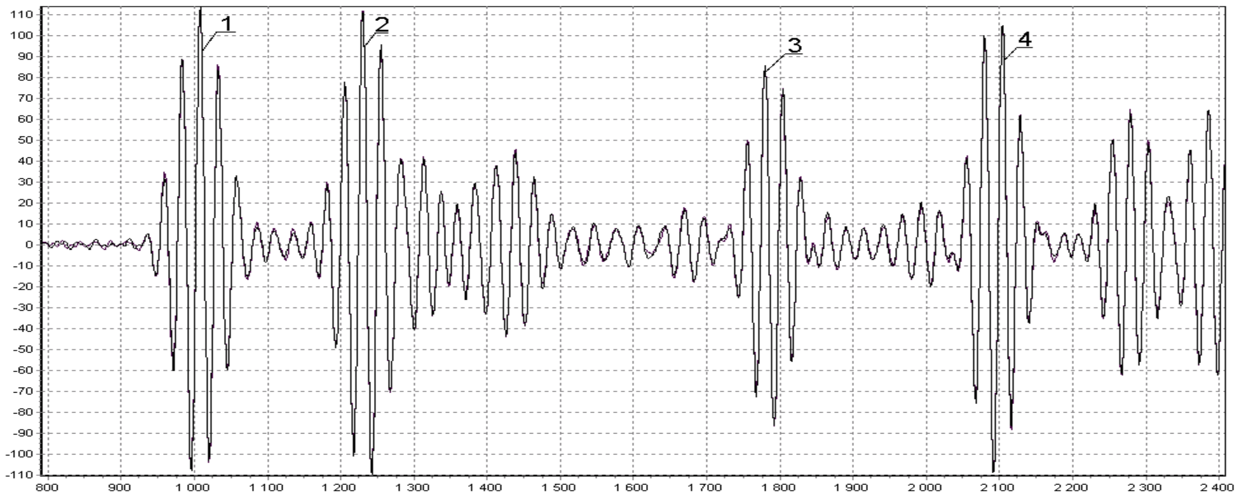


Figure 5. Temporal distribution of signals.

For this purposes the firmware part of device is used. It includes powerful digital signal processor which operates with frequency of 100 MHs and several supplemental processors which control the power consumption, process the signals from pressure and temperature transmitters, convert flow rate values to the standard conditions, operate with external interfaces, record data to archives, make some additional operations and calculations.

The important feature of developed device is the possibility of continuous autonomous operation for more than a year from the built-in lithium battery. Flowmeter can be installed to the gas pipelines of diameters from 100 to 1600 mm by the following methods:

- Flowmeter installation to the stopped pipeline with bleed down pressure. The set of special technological accessories is developed for this type of installation to adhere geometric dimensions between transducer weldolets installation points.
- Flowmeter installation to the running pipeline under operating pressure including welding. For this purpose the special device is developed and separately certified for tie-in under the operating pressure. This device can be used for tie-in and replacement of piezoelectric transducers in running pipelines under pressures of up to 100 kg/cm. Tie-in device is possible to drill out the pipelines with up to 26 mm wall thickness by castellate or hollow milling cutters of 19 mm diameters.
- Flowmeter can be installed on the measuring pipeflange.

The developed flowmeter is certified and passed through all types of tests. Basic flowmeter model consists of electronics unit, pressure (overload or absolute) and temperature (laid-on or immersion) transmitters and four piezoelectric transducers which use two independent channels of flow velocity measurement.

Gas flow rate and volume are calculated in accordance with the measurement procedure for ultrasonic flowmeters developed by

"Gazmetrologiya" enterprise. This procedure is Standard for all JSC "Gazprom" subsidaries. Physical properties of natural gas are calculated in accordance with the requirements of GOST 30319.1 and GOST 30319.2 by methods of NX19mod, GERG91mod and AGA8-92DC.

Flowmeter records in the built-in nonvolatile memory, displays on the built-in indicator and output to the external port the average-hourly and average-daily values of overload (absolute) pressure, flow rate under operating conditions, temperature, measured medium volume and combustion heat rate. Besides it records data about operator or information system interferences in any flowmeter parameters. Hour data files depth is 50 days, daily data files depth - 600 days, interferences archive depth – up to 1200 reports.

Flowmeter automatically register in time the emergency situations, concerned with breakdown of transducers, measuring channels, with reduction of the built-in battery voltage, etc.

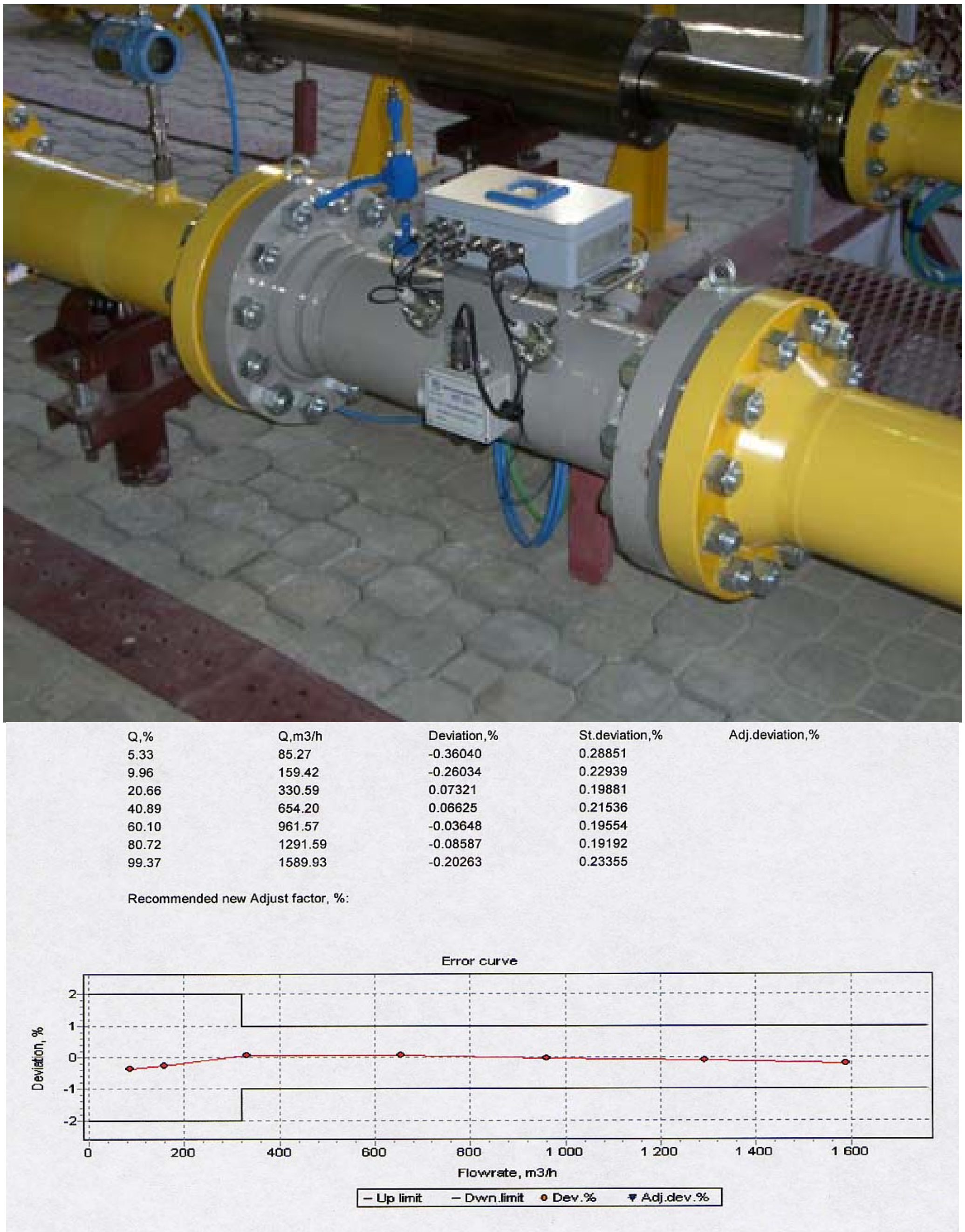
Parameters of device can be configured by infrared port of portable terminal or by terminal program installed on technological computer. Terminal program can read data files and interferences archives via EIA RS-232 interface from 16 devices "HyperFlow-US".

The limit of tolerable relative accuracy of gas flow rate and volume measurement under operating conditions on indicator and digital output of flowmeter is no more than ± 0,75% (for the model with pipeflange). Herewith, the range of measured velocities wides from 0,3 up to 40 m/s.

For checking up its metrological characteristics the flowmeter was tested in Ural Regional Metrological Center of "Gazprom". Turbine gas flowmeter "Instromet International" of SM-RI-X-L model was taken as an etalon measurement device. Its relative flow rate measurement accuracy was 0,2% while the latter of "HyperFlow-US" was no more than 0.28% as it can be seen from the Fig. 6.

Flowmeter is calibrated on the special calibration rig via "Poverka.exe" program. Calibration rig is the section of pipeline of

Du=150 mm blinded from two sides with the installed weldolets for positioning of device transducers (Fig.7).



Q,%	Q,m3/h	Deviation,%	St.deviation,%	Adj.deviation,%
5.33	85.27	-0.36040	0.28851	
9.96	159.42	-0.26034	0.22939	
20.66	330.59	0.07321	0.19881	
40.89	654.20	0.06625	0.21536	
60.10	961.57	-0.03648	0.19554	
80.72	1291.59	-0.08587	0.19192	
99.37	1589.93	-0.20263	0.23355	

Recommended new Adjust factor, %:

Figure 6. Ultrasonic flowmeter on the measuring pipeline of Du=200 mm.

Calibration process includes measurements of sound velocity in stable medium along different acoustic ways both under atmospheric pressure and pressures up to 50 kg/sm^2.

Sound velocities, being measured by device along different acoustic ways, must be identical. Subsequently nitrogen will be used for filling the calibration rig. Sound velocity in nitrogen is tabulated with high accuracy. Calibration rig can be used in the regional centers of standardization for periodic calibration of operating ultrasonic flowmeters. Inter-calibration interval of flowmeter "HyperFlow-US" is 2 years.

Figure 7. Calibration acoustic rig.

The examples of measuring units based on ultrasonic flowmeter "HyperFlow-US" on the pipelines of different diameters are shown on the Fig. 8.

Figure 8. Examples of measuring units.

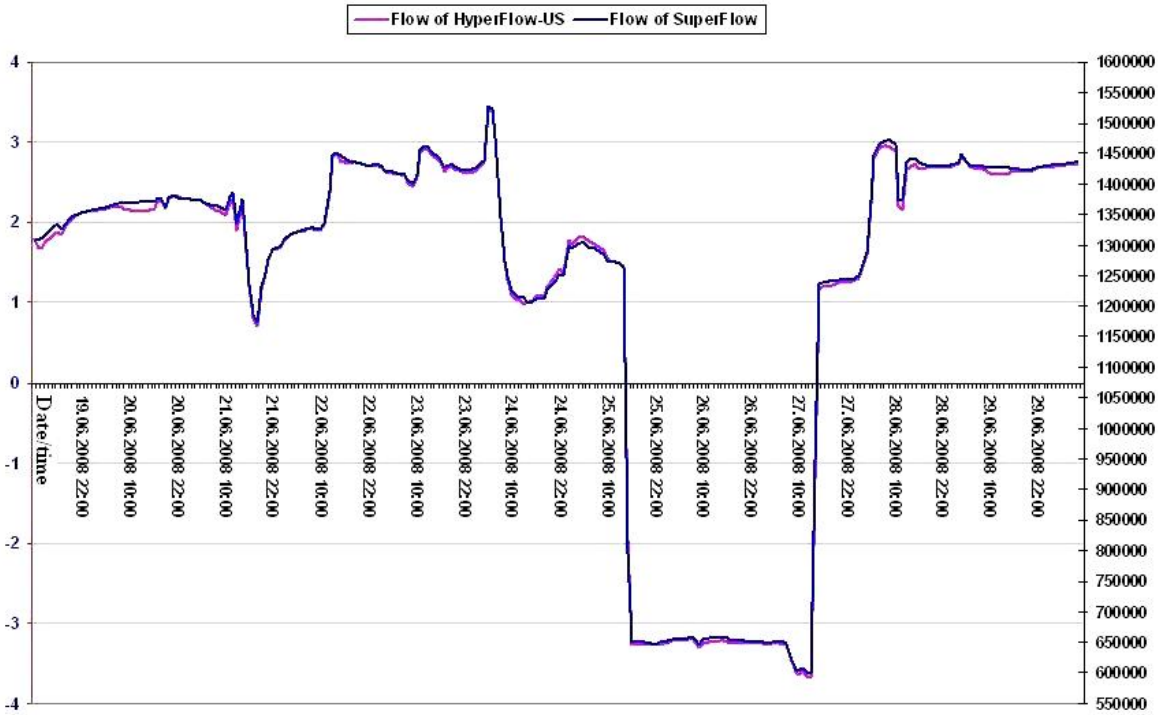


Figure 9. Diagram of flow rates, measured by ultrasonic and pressure differential flowmeters.

Presently, the complex flow rate measuring unit with the possibility of measurements means auto-calibration during operation process is developed with the use of ultrasonic flowmeter "HyperFlow-US" as base model.

Optionally measuring unit can include means for gas quality control such as hygrometer and gas chromatograph. The main advantage of this measuring unit will be considerable cost reduction of building and current operation.

3. REFERENCES

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4. LIST OF FIGURES