Practical experience of using ultrasound flowmeters at the measurement associated petroleum gas

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Abstract. The results of field tests of several ultrasound flowmeters at existing oil and gas extraction objects are given in the paper. Measured medium – associated petroleum gas. This work aims to create a unified system for measuring the amount and parameters of APG in order to reduce operating costs.

1. Introduction
Associated petroleum gas (APG) defined as a gas dissolved in oil, which is extracted from the bowels of the earth with oil. This gas is separated from oil by a multi-stage separation on the oil treating and production objects.

According to [1,2] APG – a mixture of hydrocarbon gases released from crude oil during its production, transportation, treatment.

For a long time the APG was burned directly at the extraction objects. However, in recent years its recycling or safe disposal takes place. It is connected with toughening of requirements in the field of environmental safety as well as the requirements in the field of rational nature management and resource saving. In this connection the problem of accounting the APG becomes relevant.

Accounting for dry natural gas in the world practice was organized long ago. Sets of measuring instruments and methods of accounting approved in practice are used such as commercially produced flowmeters based on different physical principles, as well as calculators with the necessary mathematical apparatus and systems of archiving parameters of the gas.

APG component composition significantly differs from the composition of natural gas. The density of the natural gas varies in the range 0.65-0.7 kg/m³. The density of the APG is strongly dependent on the component composition and may vary in the range 0.7-1.5 kg/m³.

The second feature is the physical behavior of the APG because of its complex component composition in the measured pipeline under different conditions.

Accounting for this gas is complicated by the fact that the droplets of hydrocarbons and water, flying in the gas pipeline, are deposited on the sensor of flowmeters, accumulate in the pipe, and the measured medium becomes non single-phase. As a result flowmeter readings are not reliable.

Our research team is working on the selection of the optimal composition measuring instrument [3] for the organization of accounting APG in the oil and gas production objects, according to [1]. This work aims to create a unified system for measuring the amount and parameters of APG in order to reduce operating costs.
Measurement system of amount and parameters APG – a set of functional united measuring instruments, data processing systems and process equipment designed to measure the amount and parameters APG, display and registration of measurement results.

In this paper the results of field studies of several ultrasonic flowmeters from various manufacturers are presented.

2. Measuring Technique
Ultrasonic flowmeters measure the volume of passing gas unlike thermal-mass [3] and Coriolis flowmeters. For accounting gaseous media is used ultrasonic flowmeters using two principles determine the flow rate. First, pulse-time method, the second, the correlation method.

Operating principle of pulse-time flowmeters is based on measurement of the difference between the time of transmission probe pulses in the direction of gas flow rate in the pipeline and the time against him. Emitting/transmitting probe pulses realized like at a most ultrasonic devices [4,5].

Ultrasonic transducers mounted on the measuring pipeline provides emission and reception of probe pulses. Electronic control unit carries out alternately switching emission/reception modes of sensor pairs. Calculator of the flowmeter using the known parameters (propagation time, the inner diameter of the pipeline and the distance between the transducers) calculates the average speed, instantaneous flow rate and generates a normalized frequency output signal proportional to the volumetric flow. The emitting and receiving transducers may be located across from each other - on opposite sides of the pipe, or on one side using reflection from the pipe wall. The advantage of this method – a wide dynamic range.

The sensor of the flowmeter s using Doppler method consists of four ultrasonic transducers, arranged in pairs diametrically in two section perpendicular to the axis of the pipeline. The operating principle of the flowmeter sensor is based on measuring the time of movement heterogeneity (small solid particles, condensate droplets) between the two pairs of transducers with a known distance between them. Two emitters radiate ultrasonic oscillations, which, after passing through the gas flow are received and converted into electrical signals in the receiver. Due to the interaction of the ultrasonic oscillations with heterogeneities in the gas flow secondary oscillations becomes phase-modulated. The modulation signal is allocated by the phase detector. Based on this signal the time of movement heterogeneity between sections is determined. Calculator performs the same function as in the first method. The advantage of this method is the relative simplicity and reliability of the physical method, no effect the gas composition on the result of flow velocity. Disadvantage – a narrow dynamic range.

3. Field Studies
The results of field studies of several ultrasonic flowmeters carried out at various times and on different oil production objects are presented in this paper. Tests of pulse-time GiperFlow-US, GUVR-011A2, FlowSic 100 flowmeters and Doppler flowmeter Dymetic-1222 were carried out.

The main parameters of ultrasound flowmeters are shown in Table 1.

| Parameter                    | Value                      |
|------------------------------|----------------------------|
| Dynamic Range                | GiperFlow-US | GUVR-011A2 | FlowSic 100 | Dymetic-1222 |
| Flow Velocity, m/s           | 0.3 to 30     | 0.1 to 35   | 0.03 to 120 |
| Volumetric Gas Discharge, m³/h| 5 to 200 000 | 1 to 10 000 | 16 to 30 000 |
| Pipeline Diameter, mm        | 100 to 1 600  | 50 to 400   | 100 to 1 800 | 100 to 600 |
| Intrinsic Relative Error, %  | ≤ 2.5         | ≤ 1.5       | ≤ 1         | ≤ 2         |

Figure 1 shows the described above flowmeters on various oil and gas production objects.
GiperFlow-US flowmeter was installed in a horizontal pipeline of feeding APG from the gas separator at oil production object. During the measurement, analysis of the results, as well as inspection of the measuring area after dismantling was concluded that the oil is ejected periodically in the APG pipeline. It is connected with a lower location of the separation tank compared with the technological tank of the oil accumulation. These points of emission are marked by peaks of high flow rate at Figure 2.

A significant excess of the measured flow rate versus the actual APG flow rate explained by the change of the medium (APG) to the denser medium (oil).

Following results of gas flow rate using an ultrasonic flowmeter HyperFlow-US were obtained: value of the hourly flow rate $Q_C$ varied in the range from $Q_{MIN} = 1.5 \text{ m}^3/\text{h}$ to $Q_{MAX} = 400 \text{ m}^3/\text{h}$ (except for oil ejection in some measurement periods). Under these conditions, a more accurate measurement should be carried out using of measuring instruments are less sensitive to contamination of the APG.

Also, the measuring system based on ultrasonic flowmeter GUVR-011A2 was manufactured (Figure 1a). This measuring system was used to determine gas flow rate to the flare pipe. The results of measurement are shown at Figure 3a.
Figure 3. The results of measurement: a) gas flow rate at the flare pipe; b) at the pipeline of feeding APG from the separator, there $V_P$ – volumetric gas discharge at the day, $V_C$ – volumetric gas discharge reduced to standard conditions.

At this object the GUVR-011A2 flowmeter may be used. Value of APG flow rate represent the actual flow rate.

This measuring system was used later to determine APG flow rate on gas supply pipeline from the separator on another oil production object. At the Figure 3b the results of daily measurements and calculations for 9 days are presented. Due to the significant pollution acoustic sensors of the flowmeter data spread of measurements and calculations is observed. Therefore to use the GUVR-011A2 flowmeter on the given object should be excluded getting the condensed fraction of the APG in the measuring pipe.

The analysis of more than 20 measuring systems (at various oil production objects) based on the FlowSic 100 ultrasonic flowmeter was carried out.

The advantage in terms of organization constant account the APG – high reliability (including in the northern regions) and the accuracy of the determination the flow rate, minimizing costs for maintenance and routine maintenance. Disadvantage – the high cost and, accordingly, the high cost of repairs in case of failure.

Finally, we consider the ultrasonic flowmeter Dymetic-1222. Fitting the flowmeter and related pressure and temperature sensors made in a horizontal pipeline of the oil production object (Figure 1a). Measurements were made within 12 days from the launch date. The results are shown at Figure 4.

Figure 4. The results of measurement the gas flow rate obtained by Dymetic-1222, there $V_P$ – volumetric gas discharge at the day, $V_C$ – volumetric gas discharge reduced to standard conditions.

From the measurement results it can be concluded that they correspond to the actual flow rate values.
Advantages of Dymetic-1222 flowmeter – stable operation in polluted medium, a relatively low price. Disadvantages – big time lag when the actual flow rate is changing, weak mathematical apparatus processing the primary signal from sensors, and a relatively high percentage of failures due to flaws components and software.

5. Conclusions
The presence of contamination in the APG flow at temperatures above the dew point no creates of difficulties for most flowmeters (in terms of working algorithms). The exception is the presence in the APG flow of solid particles (e.g., sulfur), which can disturb the operation of sensitive elements some models of flowmeters and cause failure of the device.

But if the APG temperature drops below the dew point, the hydrocarbons begin to condense in the flow (until the appearance the liquid phase) and at the sensors.

At still lower temperatures, liquid fractions crystallize and deposit in the form of a solid crust on the pipeline and sensors. In addition distorting the measurement results, this leads to the failure of some models of flowmeters. In exceptional cases, this leads to a complete APG flow shutoff.

Also aggressive medium of APG may negative impact on the sensors. If the sensor is not protected metallized flask, corrosion and destruction the sensitive part of sensor can occur. In addition, the presence of a second phase (condensed heavy hydrocarbons or emergency ejected oil and other oil fractions) distorts received primary signal. Therefore, the accuracy of accounting in these conditions becomes questionable. Figure 5 shows the flowmeter sensors are polluted with oil.

![Figure 5a. Polluted sensor of FlowSic 100 flowmeter.](image)

![Figure 5b. Polluted sensor of GiperFlow-US flowmeter.](image)

Approach to solving these problems an individual. Somewhere solution is using of gob deflector, somewhere installation of additional separator, somewhere changing technological line, or transfer the flowmeter to another location.

In conclusion, it should be noted that the use of ultrasonic flowmeters is limited to the high cost. It is starting from 30 000 euros for set.

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