Practical experience of using thermal-mass flowmeters at the registration associated (free) petroleum gas

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Abstract. The results of field tests of thermal-mass flowmeter TurboFlow TFG-S in comparison with ultrasonic flowmeter Dymetic-1223K at existing oil and gas extraction object are given in the article. Measured medium – associated (free) petroleum gas.

1. Introduction
The general trend of increasing volumes of hydrocarbon production in the world today caused by the increasing needs of the industry. For a more rational use of the products extraction and reducing polluting the biosphere emissions by burning in the Russian Federation developed and released a number of documents.

In particular, Resolution № 1148 of 11.08.2012, "On peculiarities of calculating fees for emissions \ldots", and the Order of the President of the Russian Federation № PR-1461 from 10.08.2007 on the rational use of associated petroleum gas (APG). They envisage:
- Maximum permissible limits burning in torch and (or) dissipation - no more than 5% of the volume extraction APG;
- Bringing usage (utilization) of APG to 95% of total extraction;
- Introduction of compulsory monthly report for the extraction and collection of APG;
- Equipment of the oil and gas production objects of APG measuring instruments (MI), in the absence of MI, which confirm the actual volume extraction, use and burning - a multiple increase penal sanctions;
- In the case of violations of the established requirements for the organization of accounting APG - recall subsoil licenses.

GOST R 8.733-2011 [1] (was put into effect 1.03.2012) is the main regulatory instrument for the organization of APG accounting, which lists the terminology, classification systems measure the amount of gas, requirements to systems measure the amount of gas and it metrological assurance.

A feature of the APG is the physical manifestation of its component composition in the measured pipeline under different conditions.

Accounting for such gas is complicated by the fact that the hydrocarbons and water droplets flying in the gas pipe are deposited on the sensitive elements of flowmeter accumulate in the pipe and are transformed into a stream of fluid, whereby indications of counters are not always reliable.
2. Equipment and Tools

There are basically two different methods for determining the flow rate (volume) of the gas: mass (obtain immediately under standard conditions) and volumetric (obtain flow rate (volume) in the working (current) conditions, which then need to be brought to standard conditions).

The former include thermal-mass and Coriolis flowmeters. The second - turbine, rotary, ultrasonic, vortex and optical.

In this article the results of field tests of thermal-mass flowmeter TurboFlow TFG-S in comparison with ultrasonic flowmeter Dymetic-1223K at existing oil and gas extraction object are given, according to [1].

Ultrasonic flowmeter Dymetic 1223K (Figure 1a) uses correlation method for determining the flow rate (Figure 1b).

**Figure 1a.** Exterior view of the ultrasonic flowmeter Dymetic 1223K.

**Figure 1b.** The operating principle of the ultrasonic flowmeter Dymetic 1223K.

Structurally flow sensor consists of four acoustic transducers, arranged by two diametrically pairs in section perpendicular to the pipeline axis.

The principle of operation flowmeter is based on measuring the transit time of the perturbed "element" of the stream (heterogeneity caused by turbulent fluctuations) between two pairs of the transducers with the known distance between them. During operation flowmeter, two acoustic emitters (Emitter 1 and Emitter 2) excited by ultrasonic frequency generators emit ultrasonic vibrations, which, after passing through the gas flow, are perceived and converted into electrical signals in the secondary acoustic receivers (Receiver 1 and Receiver 2).

Due to the interaction of ultrasonic beams with inhomogeneous in the gas flows secondary oscillations are modulated in phase. The modulation signal is allocated by the phase detector. Then time of the heterogeneity between sections 1 and 2 is defined. The calculator of flowmeter with known times and a given geometric dimensions (inner diameter of the pipeline, the distance between sections 1 and 2, the roughness of the pipeline walls) calculates the average speed, instantaneous flow and generates normalized frequency output signal proportional to the volumetric flow.

A positive feature of this method is its relative simplicity and reliability of the physical method and the absence of the influence of the gas composition on the determination result of the flow velocity. The disadvantages - a narrow dynamic range.

The principle of the thermal-mass flowmeter TurboFlow TFG-S is that the medium washing the heated temperature sensor, carries away with itself certain part of the thermal energy transducer. In the thermal flowmeters medium bends around two temperature sensors. One sensor provides the reference value - the temperature of the medium. The second sensor is a heated element that gets exactly as much energy to compensate for the thermal dissipation and maintain a well-defined temperature difference. The larger the mass flow washes heated sensor, the more heat energy is dissipated, and the more power must be supplied to the sensor to maintain a temperature difference. Thus, the current in the heating circuit of the sensor is measured parameter determining the gas mass flow rate.
3. The experiment scheme

Objective: To determine actual flow rate of the APG and the choice of means for measuring its accounting.

At the facility "Prikamneft" "Elabuga UPS" were consistently set measuring computer complex (MCC) APG (reg. № 47248-11 in the State Register of Measurement) consisting from ultrasonic flowmeter Dymetic-1223K (correlation method), calculator VTD-U, temperature sensor and absolute pressure (as a control) and the flowmeter TurboFlow TFG-S (as working (test)). Mounting diagram is shown in Figure 3. Collection of information about the flow rate of the APG was conducted for 36 days.

![Figure 3. Mounting diagram of measurement instruments](image)

Chosen mounting circuit (Figure 3 and Figure 4 – gas flow direction – from left to right) of measuring instruments excludes the mutual influence (Ultrasonic flowmeter and the pressure sensor do not disturb the flow velocity profile of gas before TurboFlow TFG-S).
4. The test results

Below are the diurnal measuring computer complex APG and TurboFlow TFG-S over the observation period (36 days), and error $\delta$ $V_p$ relative to the volume APG, measured and reduced to standard conditions measuring computer complex APG $V_K$, calculated by the formula [2]:

$$
\delta = \frac{V_p - V_K}{V_K} \cdot 100\% ,
$$

(1)

where $V_p$ – volume APG, measured and reduced to standard conditions by flowmeter TurboFlow TFG-S, $V_K$ - volume APG, measured and reduced to standard conditions by measuring computer complex APG.

![Figure 5. Graph changes daily flow rate and the relative error.](image)
As seen from the graph, changes daily flow rate over the period of observation on both devices takes place constant component of the error in determining the flow rate by flowmeter TurboFlow TFG-S, which is caused by the exercise calibration on natural dry gas. And also is present a recurring error caused by the pollution of sensitive elements of the device, which leads to unpredictable disruption dynamics of heat transfer and distortion of results.

5. Conclusions

In the analysis of the obtained results, we can draw the following conclusions: physical method of flow measurement TurboFlow TFG-S is unreliable when used on associated (free) petroleum gas, which is usually is present the second phase in the form of oil vapor, hydrocarbons and water. However, it should be noted that the use of self-cleaning function of the sensing elements of the probe can maintain working capacity of the flowmeter for a long time without intervention of staff.

Thus, when using a thermal-mass flowmeter for the wet free gas it is necessary to consider that the heat and mass transfer characteristics vary significantly depending on the composition and properties of the medium. Therefore, need to calibrate the flowmeter at the same gas composition and properties, or the development and application of a mathematical algorithm in determining the speed (flow rate) of the medium at its various compositions and properties.

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References
[1] GOST R 8.733-2011 System parameters and measurements of the amount of free gas. General metrological and technical requirements (Moscow: Standartinform) p 32
[2] GOST R 8.615-2005 Measuring the amount extracted from subsurface oil and gas. General metrological and technical requirements (Moscow: Standartinform) p 23