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OPERATING FEATURES OF NATURAL GAS FLOW MEASUREMENT SYSTEMS

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Energy resources accounting is a component of their rational consumption. The outdated equipment use that does not meet the requirements for measurement accuracy is one of the main issues in natural gas metering. Therefore, the issues of creating high-precision gas metering systems remain relevant. Gas metering units are used at various sites, from boiler houses to gas distribution stations and points that have different requirements for metrological performances and characterized by different operating conditions.

To improve the gas metering quality, it is necessary to control its physical and chemical parameters, such as pressure, temperature, density, gas composition, etc. Therefore, the creation of systems for measuring the flow and quantity of natural gas requires an integrated approach that includes recording, processing and monitoring all necessary parameters using data transmission technologies.

The automated collection lack and information conversion from the measuring system components makes it impossible to remotely monitor its state.

The aim of the work is a comparative analysis of existing systems for measuring the flow and quantity of natural gas, as well as the requirements' formulation for an automated system for measuring its parameters.

The functioning features of existing systems, their structure and technical performances are discussed in the article. An analysis of current approaches to energy carrier accounting has been conducted.

Particular attention is paid to the requirements for algorithms for processing and converting information received from automated systems for measuring natural gas flow rate, in addition to bringing the gas volume to base conditions and calculating the consumed energy quantity. General requirements for such systems, which contribute to increasing the accuracy and reliability of measurements, are formulated.

The prospects for further work are to improve an algorithm for the interaction between the measurement system components.

Key words: *natural gas, flow rate, measurement, measuring system.*

Introduction. Problem statement

There are many different serious issues in the field of energy metering, especially natural gas. They are associated, first of all, with the use of outdated equipment that does not meet the requirements for measurement accuracy, the absence of devices for remote data transmission and built-in self-diagnostic algorithms at metering units.

Natural gas is an important non-renewable natural energy resource. Its extraction, transportation and consumption must be controlled and measured with the high precision, which requires special attention in boiler houses, industrial plants, as well as gas distribution stations and points.

Requirements for the organization of metering units are standardized and clearly regulated by legislative **bodies/services** and relevant regulatory documents [1].

There are a large number of natural gas flow control instruments that are based on different measurement methods. But to achieve high accuracy in flow rate determining and obtain information about actual gas consumption, it is necessary to control its physical and chemical parameters, such as pressure, temperature, density, composition, etc.

To solve the issue of precise control of gas flow and quantity, an integrated approach is used, which involves recording, processing and monitoring all necessary parameters using certain data transmission interfaces [2, 3].

The automation of the collection and conversion of information from devices and instruments, and, as a consequence, the possibility of remote control of their performance are increasing the overall reliability of energy accounting.

The gas metering system configuration is selected depending on the number of measurements, as well as operating conditions. In this case, either a flow meter with built-in pressure and temperature sensors is used, or, in the case of a panel design, separate devices and control instruments are installed.

The aim of the work is a comparative analysis of existing systems for measuring natural gas flow rate, their structure, technical performances and

application features, as well as the formulation of requirements for an automated system for measuring natural gas parameters.

Gas metering systems' organization

According to the [1], the gas volume must be converted into the consumed energy quantity. Taking this into account, the generalized structure of the gas metering **unit** contains the following components:

- Measuring devices:
  - primary gas flow transducer (as a part of meter or flow meter);
  - pressure sensors;
  - temperature sensors;
  - gas analyzers;
- Computing devices that implement the reduction of the consumed gas volume to base conditions;
- Computing devices that implement the calculation of the consumed energy quantity based on volume value.

The basis of the natural gas parameter measurement system is the flow transducer which is the part of the flow meter or meter. Among the wide variety of flow determination methods, the most frequently used transducers for measuring gas flow are those based on the variable pressure difference method, tachometric methods, vortex and ultrasonic [4, 5].

The transducer choice for a gas metering system is determined by the operating conditions, which are characterized by the range of changes in flow rate, temperature and pressure of the measured medium, its chemical composition, as well as the list, nature and intensity of the influencing factors manifestation.

Various data transmission technologies are used to organize remote signals transmission from different elements of the system.

All values of the measured gas volume V are reduced to standard conditions V_{ST} using the formula [6]

$$V_{ST} = C \times V .$$

Where, C is a coefficient, the value of which is calculated by the values of pressure, temperature and compressibility coefficient under base and operating conditions

$$C = \frac{P}{P_{ST}} \times \frac{T_{ST}}{T} \times \frac{Z_{ST}}{Z} .$$

Where, P, T and Z are pressure, temperature and compressibility coefficient respectively under operating conditions. P_{ST}, T_{ST}, Z_{ST} are parameters of the measured flow under base conditions.

Calculation and conversion of gas volumes to standard conditions is carried out by electronic devices.

These devices also store information and calculate gas consumption in units of consumed energy quantity.

Different algorithms are used to bring the consumed gas volume to base conditions [7 – 9]:

- The T-conversion is carried out as a function of temperature only; in this case, only the primary temperature transducer is connected to the computing unit, the pressure is not measured; the fixed pressure value, as well as, the compressibility coefficient value is taken into account as constants.
- The PT-conversion is implemented as a function of pressure and temperature with a constant compressibility factor; primary pressure and temperature transducers are connected to the computing unit; in this case, the compressibility factor is considered as a fixed value calculated on the basis of average measurement conditions and a known gas composition.
- The PTZ-conversion is carried out taking into account the values of pressure, temperature and compressibility coefficient of the measured gas.

Determining the consumed energy quantity by volume also involves the presence of various components and functions, and is characterized by the following design features:

- a means of determining the combustion heat is used as a separate metering unit component;
- without local installation of a means for measuring the combustion heat; in this case, a fixed value of the combustion heat signal or a signal that is periodically updated is entered into the computing unit.

In our country, gas metering systems are created on the basis of volumetric and mass flow meters, absolute and over-pressure transducers, and resistance temperature transducers [10 – 15]. In this case, instruments of the rotary, turbine, membrane, vortex, and ultrasonic classes are used, as well as using the method of variable pressure drop with a standard narrowing device or with an averaging pressure tube. The algorithms of the computing devices usually provide the ability to process the signals of the measuring transducers on several lines, as well as on a bypass line. The characteristics of the measuring systems are given in Table 1.

As the performances analysis result of natural gas flow measurement systems, the following features of their operation were identified:

- all the systems considered implement the conversion of the measured gas volume into consumed energy units;
- in accordance with [16], the verification period for measuring systems is two years (for class 1.0);
- as an overall approach, energy conversion devices are tested as a whole, by testing the functions of the energy calculator, volume conversion [8];
- measuring systems may have the ability to replace the primary flow transducer without loss of measurement quality;

– the algorithms of the computing units use different methods for calculating the compressibility coefficient;
– the computing capabilities of measurement system conversion devices differ by the ability to take into account the physical and chemical parameters of the gas for the precise conversion of the consumed volume into the consumed energy quantity (a wide or limited list of only the necessary values).

Table 1. Performances of natural gas flow measurement systems

System name	**КВТ-1.01А** [10, 11]	**КВР-1** [12, 13]	**ФЛОУТЕК – ТМ** [14]	**ДАНИФЛОУ** [15]
Manufacturer	СП «Радміртех»	СП «Радміртех»	ТОВ "ДП УКРГАЗТЕХ"	ТОВ "НВП "УКРІНТЕХ"
Country	Kharkiv, Ukraine	Kharkiv, Ukraine	Kyiv, Ukraine	Kharkiv, Ukraine
Size	G250	G250	Depending on the class of the flow meter in the system	Depending on the class of the flow meter in the system
DN	80	80	–*	–
Q_{MIN}, m^3/h	8	1.6	by variable pressure drop method; rotary; turbine; ultrasonic; vortex	by variable pressure drop method other compatible meters
Q_{MAX}, m^3/h	400	400	–	–
Measurement range	1:50	1:250	–	–
Operating temperatures	-25 ºC to +55 ºC.	-25 ºC to +55 ºC.	-40 ºC to + 70 °C	-40 ºC to + 70 °C
Pressure loss, Pa	2500	900	–	–
Bounds of the basic permissible relative error	$0.1 \cdot Q_{max} \le Q \le Q_{max}$ ± 1 % $Q_{min} \le Q < 0.1 Q_{max}$ ± 2 %	$0.05 Q_{max} \le Q \le Q_{max}$ within ± 1 %; $Q_{min} \le Q < 0.05 \cdot Q_{max}$ within ± 2 %.	±0,3 to ±1,9 %.	–
Compressibility coefficient calculation	NX19 mod. GERG 91 mod.	NX19 mod. GERG 91 mod.	NX-19 mod, GERG-91 mod, SGERG-88, AGA8, by the chromatograph data, or entering the appropriate parameters	GERG-91 mod. NX-19 mod. SGERG-88 AGA8-92DC
Protection class				
explosion class	II 2G Ex ib IIA T4 Gb	II 2G Ex ib IIA T4 Gb	II 2G Ex ib IIB T3 Gb	II 2G Ex ib IIA T5 Gb
external mechanical conditions class	M2	M2	M2	M2
external electromagnetic conditions class	E2	E2, strength not more than 400 A/m	E2	E2
protection class	IP65	IP65	IP65	IP55

*no information provided

Therefore, the automated system for measuring natural gas flow rate must meet the following requirements: /such requirements as
– continuous operation;
– constant/ unchangeable/ invariable measurement range (can be provided by additional measurement lines);
– determination of pressure and temperature with a given accuracy;
– calculation of the measured medium compressibility for different operating conditions and parameters of the measured medium by appropriate methods;
– bringing the volume consumed gas volume to base conditions;
– the consumed energy amount calculation based on the measured gas volume;

- high protection class from external (mechanical, climatic, energy) influences and internal technological factors;
- indication of measured and calculated parameters;
- indication of emergency situations;
- archive of information accumulation;
- the ability to select
  - the archive depth (month, quarter, half-year, etc.);
  - the archive step (hour, day, week, month, etc.);
- emergency log;
- the presence of a remote data transmission interface.

The gas volume measurement accuracy is determined by the class of the system primary flow transducer. The authors proposed the automated system creation using an ultrasonic flow transducer with a complex trajectory of the measuring beam [17].

Conclusions

Information on the structure, functional capabilities, technical performances and operating features of natural gas flow measurement systems are summarized.

Complex systems for measuring and monitoring consumed gas, which are manufactured in Ukraine, their possible designs and performances are analyzed.

General requirements for automated systems for measuring natural gas flow rate have been formulated.

The prospects for further work are to improve an algorithm for the interaction between the measurement system components.

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ОСОБЛИВОСТІ ФУНКЦІОНУВАННЯ СИСТЕМ ВИМІРЮВАННЯ ВИТРАТИ ПРИРОДНОГО ГАЗУ

Облік енергетичних ресурсів є складовою їх раціонального споживання. Одною з основних проблем обліку природного газу є застосування застарілого обладнання, яке не відповідає вимогам до точності вимірювань. Тому питання створення високоточних систем обліку газу лишаються актуальними. Вузли обліку газу встановлюються на різних об’єктах, починаючи від котелень і закінчуючи газорозподільчими станціями та пунктами, що мають різні характеристики.

Для підвищення якості обліку потрібно контролювати його фізико-хімічні показники, такі як тиск, температура, густина, газовий склад тощо. Отже створення систем вимірювання витрати та кількості природного газу потребує комплексного підходу, який передбачає фіксацію, обробку та контроль усіх необхідних параметрів із застосуванням певних технологій передачі даних.

Відсутність автоматизованого збору та перетворення інформації від компонентів вимірювальної системи унеможливлює дистанційний контроль її стану.

У статті розглянуто особливості функціонування існуючих систем, їх структури та технічних характеристик. Проведено аналіз актуальних підходів до обліку енергоносія.

Основну увагу приділено вимогам до алгоритмів обробки та перетворення отриманої інформації від автоматизованих систем вимірювання витрати природного газу, зокрема приведенню об'єму газу до стандартних умов і розрахунку кількості спожитої енергії. Сформульовано загальні вимоги до таких систем для підвищення точності та достовірності вимірювань.

Перспективою подальшої роботи є вдосконалення алгоритму взаємодії складових системи вимірювання.

Ключові слова: природний газ, витрата, вимірювання, вимірювальна система.

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