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THE MAIN PROBLEMS OF FLOW MEASUREMENT IN THE GAS TRANSPORTATION AND GAS DISTRIBUTION SYSTEM AND THE PROPOSED SOLUTIONS

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Flow measurement is a branch of metrology that deals with the quantitative determination of the medium (gas, liquid or steam) passing through a pipeline or system under certain conditions. In general, metrology is a pillar in the gas transportation and distribution system, the correct operation of which contributes to gas accounting, loss calculation, production cost reduction, as well as accurate assessment of environmental impact and protection of consumer and employee safety. In addition, let's not forget the words of Lord Kelvin: "If you can't measure it, you can't fix it."

The correct and comparable determination of gas flow throughout the gas transportation system contributes to the transparency of energy resource calculations and allows for their real savings, since the quantitative assessment of the impact of energy saving measures allows us to determine the loss of energy resources on the way from source to consumer. In addition, the determination of gas consumption is important for establishing correct commercial relations between the natural gas supplier and the consumer, as well as for analyzing the optimal management of gas supply and transportation modes, compiling a gas balance in gas transportation and distribution systems, and exercising control over the rational and efficient use of gas.

Gas has certain physicochemical properties, and its quantity and volume strongly depend on environmental conditions and on the quantities that can affect the measurement process. Also, in order to ensure the uniformity of measurements carried out in the gas transportation and gas supply system and to make the measured volumes of gas flow comparable, the measured flow should be brought to standard conditions, since in the gas transportation system the gas flow is measured at different temperatures and pressures, and therefore also at different densities.

Keywords: metrology, flowmeter, metering device, measurement method, measurement principle.

Introduction. This article considers a new modified flow meter with a built-in electronic corrector with an optical coupling and a special programmed software that meets the current legislative and production demand of Republic of Armenia, the widespread use of which, at least in the areas of legal metrological control, that

is in commercial transactions will contribute to the correct cost estimation of the gas sold and high degree of protection (from an unauthorized operation).

Research methods. The experience accumulated over recent years, during which thousands of modern flow meters, electronic correctors and measuring systems have been operated and their positive and negative aspects have been considered, makes it possible to consider the requirements and solutions for gas flow metering in the gas transportation system that are necessary for accurate and reliable measurements.

In the gas transportation and supply system, three levels of flow measurement can be observed, which are closely related to each other and must be implemented identically, that is, the uniformity of measurements must be maintained. These levels, in terms of their operational significance, are as follows:

1) measurements in commercial transactions, which are carried out in accordance with the legislation of the given country, on a contractual basis,
2) measurements carried out in and between the gas transmission and gas supply systems, which are aimed at allocating costs between the enterprise's divisions,
3) operational control, related to obtaining information about the amount of consumption, which is used in technological process regulation and management systems [1].

The following are important in gas flow measurement: high measurement accuracy over a wide range of changes in physical quantities, reliable operation in the temperature and atmospheric pressure range typical for the climatic conditions of the region, reliability of readings throughout the entire interverification period, as well as autonomy of operation, ease of maintenance and verification work.

When choosing a measurement method and auxiliary measuring instruments, the following quantities affecting the measurement result must be taken into account:

- distortion of the kinematic structure of the flow,
- the effect of mechanical impurities,
- the effect of the presence of liquid,
- blunting of the input edge of the orifice plate, which leads to a change in the coefficient and a corresponding increase in the error [2],
- pressure sampling hole discrepancies,
- factors affecting the accuracy of temperature measurement: heat transfer between the measuring pipeline and the temperature transducer, the connection line of the temperature transducer to the electronic corrector,
- unstable flow,

- irregularities in the inner wall of the measuring pipeline,
- instability of the gas composition [3].

The following gas flow measurement principles can be distinguished, which are based on:

hydrodynamic measurements.

- pressure drop measurement method,
- vortex.

measurements made with a constantly moving body.

- tachometric (volumetric),
- power.

measurements of physical phenomena.

- thermal,
- acoustic,
- electromagnetical,
- optical.

Let us consider the positive and negative aspects of the gas flow measurement methods used in our country, giving priority to the possibilities of external interference, which leads to distortion of the flow measurement results and disruption of the uniformity of measurements in the gas transportation system. The observations are given in Tables 1-2 below.

Table 1

The pressure drop method

The measurement method
The pressure drop method
The measuring equipment
Measuring system (FloBoss 103/107)
Features
• *Orifice plate* • *Measuring pipeline with straight sections* • *Pressure drop measurement device, thermometers* • *Measurement result processing device* • *Impulse lines*
Positive aspects
• *The simplicity of the flowmeter design, which allows it to be verified without a verification stand*
Negative aspects

• *Small measurement range (previously it did not exceed 1:3, but now, thanks to the emergence of multi-layer intelligent pressure sensors, it has increased to 1:10)* • *High sensitivity to the unevenness of the flow velocity profiles at the inlet of the orifice plate, which is caused by the presence of hydraulic resistances (shut-off valves, elbows, etc.) in the supply pipelines.* • *The above circumstance creates the need for a straight pipeline section with a minimum length of 10D before the orifice plate.*
Possibilities of external intervention
• *Via the orifice plate* • *Measuring pipeline due to violation of straight sections* • *Via the pressure drop measurement devices* • *Through thermal converters* • *Through a series of manipulations in the measurement result processing device* • *Through distortions in pulse lines*

Table 2

The volumetric method

The measurement method
The volumetric method
The measureming equipment
Rotary flowmeter
Features
• *Flowmeter* • *Temperature and pressure measuring device or electronic corrector (reed switch or magnetic coupling)* • *Measuring instruments for determining gas quality indicators (not used in the territory of Republic of Armenia)*
Positive aspects
• *Large measuring range with relatively small dimensions (1:100, 1:160, 1:200)* • *Energy independence* • *Durability* • *Ability to monitor the correct operation of the meter during operation by means of pressure drop* • *Insensitive to short-term overloads*

- *Stability of the conversion coefficient efficiency in the widest range of Reynolds numbers of the gas flow (calibration with air at zero excess pressure, operation with gas at operating pressure)*
- *No dynamic error in continuous (pulse) mode*
- *No straight sections*
- *Working pressure up to 7.5 MPa*

Negative aspects

- *High noise level during operation*
- *The need for a high degree of purification of the measured gas (filtration degree not less than 0.07 mm)*

Possibilities of external intervention

- *Using magnetic field to deteriorate reed switch or magnetic coupling*
- *By stopping the flowmeter rotors*
- *By disrupting the connection lines (pulses) between the flowmeter and the corrector*
- *By a number of unauthorized, but possible, interventions in the corrector*

Having studied the flow meters operating on different principles used in the territory of Republic of Armenia, let us now consider the measurement method [4] according to which the above-mentioned flow meters perform measurements, both direct and indirect. From a metrological point of view, direct measurements are more reliable and accurate, since in the case of the direct measurement method, the desired value of a physical quantity is obtained immediately, while in the case of indirect measurements, the value of a physical quantity is determined based on the results of direct measurements of other physical quantities functionally related to the desired quantity [5]. It is important to understand that indirect measurements may contain some uncertainty or error because they involve many steps and calculations. These errors can arise both from measurement inaccuracies and from limitations in the physical laws and models used to perform the calculations. However, not all measurements can be made directly, and for this purpose, when making indirect measurements, it is important to take into account the uncertainties and errors at each step, which can result in an accumulated overall error. This allows us to assess the accuracy and reliability of the data obtained to the extent possible.

Regarding natural gas flowmetering, the most efficient and suitable flowmeters can be identified based on the characteristics of the gas, while taking into account regional climatic features, the worldview of the operators, as well as the legislative framework of the given country in the case of commercial calculations.

According to Article 13 of the RA Law on Ensuring the Uniformity of Measurements dated 08.02.2012 [6] and the Decision of the RA Public Services Regulatory Commission N 536-N dated 14.12.2022 [7], commercial metering devices in the territory of Republic of Armenia are subject to legal metrological control: type approval, verification and, if necessary, metrological expertise.

According to the decision of the Public Services Regulatory Commission of Republic of Armenia N 536-N dated 14.12.2022 [7], we can distinguish between household and industrial metering devices. Household meters are intended for subscribers with household consumption, while industrial meters are intended for corporate subscribers. Household metering devices in the territory of the Republic of Armenia are equipped with temperature and pressure correctors at the initiative of the subscriber, and industrial metering devices are mandatorily equipped with auxiliary devices that record thermotechnical indicators.

The RA HO-22-N Law on Ensuring the Uniformity of Measurements dated 08.02. 2012. Article 15, Part 6, “Measuring instruments of social and vital importance, the requirements for them and the procedure for placing on the market whill be established by the Government of Republic of Armenia”, is subject to the RA Government Resolution No. 60-N dated 29.01.2016 [8], which defines the measuring instruments of social and vital importance, the requirements for them and the procedure for placing on the market. The above-mentioned government decision also applies to metering devices, such as gas meters and volume conversion devices, the results of which are used in commercial transactions between the buyer and the seller, and in settlements between the manufacturer and the seller, where the minimum technical and metrological mandatory requirements for metering devices subject to legal metrological control applied in the territory of Republic of Armenia are defined, which are as follows:

"1) satisfactory operating conditions: a. the gas flow range must comply with the following conditions."

Table 3

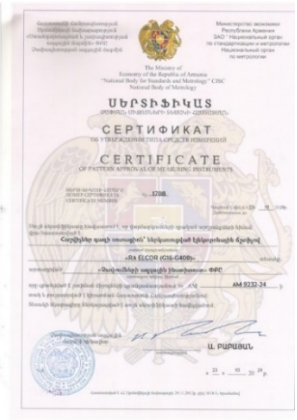
Gas flow ranges and accuracy classes of metering devices used throughout Republic of Armenia

Accuracy class

Class	Q_{max}/Q_{min}	Q_{max}/Q_t	Q_r/Q_{max}
1,5	≥ 150	≥ 10	1,2
1,0	≥ 20	≥ 5	1,2

Resaearch results. Based on the above, we can clearly state that the expediency is given to volumetric flow meters operating using the direct measurement method, the measurement range of which meets the requirements of the RA Government Resolution No. N60-N dated 29.01.2016. We can note that the pressure drop and turbine flow meters do not meet the requirements of the RA Government Decision, therefore they cannot be used in the areas of legal metrological control. Membrane flow meters are mainly used for small costs (residential subscribers), and for larger costs, it is advisable to use rotary flow meters, still the coupling of electronic corrector and the software security must be modified, so the possibility of external interference can be reduced, which will be discussed below.

Taking into account the problems that have arisen in the gas transportation and gas supply system, as well as the climatic features of the region and the worldview of the operators of the measuring instrument, a rotary flowmeter has been designed that meets the legislative and special requirements of Republic of Armenia (see RA type approval certificate, Fig. 1), the thermotechnical recording auxiliary devices of which are built into the flowmeter, i.e. the flowmeter does not need to be supplemented with auxiliary devices: electronic correctors, thermometers, differential manometers, etc., without creating any possibility of external interference (see external appearance of the flowmeter, Fig. 2) and instead of the reed switch or magnetic coupling, an optical coupling is used, so no magnetic field can affect the final calculations, as well as additional straight sections of the measuring pipeline or other complex structures are not required to install the flowmeter, i.e. the influencing quantities and the uncertainties arising from them are minimized.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СЕРТИФИКАТ
CERTIFICATE

Fig. 1. RA ELCOR (G16 – G400) rotary flowmeter type approval certificate

Fig. 2. Appearance of the RA ELCOR (G16 – G400) rotary flow meter

The main components of the RA ELCOR (G16 – G400) rotary flow meter are the measuring chamber, two rotors interconnected by a pair of synchronizing gears, two covers, the counting mechanism, and the electronic corrector. The measuring chamber consists of two figure-of-eight rotors that rotate relative to each other, moving an amount of gas from the meter inlet to the outlet equal to the volume between the rotor and the measuring chamber wall. The rotations of the rotors are synchronized by means of gears. The rotors and chamber are designed to ensure the maximum tightness during rotation, which, in turn, results in the minimum amount of unaccounted gas leakage. The rotor rotations are transmitted to the counting mechanism through an optical coupling. Directly from the rotors, high-frequency pulses are counted by an optical sensor using an electronic corrector built into the device, which, in turn, measures the working pressure and temperature of the gas using an "NTC" type semiconductor thermocouple and an absolute pressure piezo sensor, and taking into account the previously introduced gas quality parameters, recalculates and brings the amount of gas passed to standard conditions.

The meter is equipped with two electronic displays. The first displays hourly, daily, and monthly costs, with their corresponding pressures and temperatures. The second display sequentially displays daily adjusted and unadjusted costs, instantaneous pressure, temperature, and hourly costs (Fig. 3).

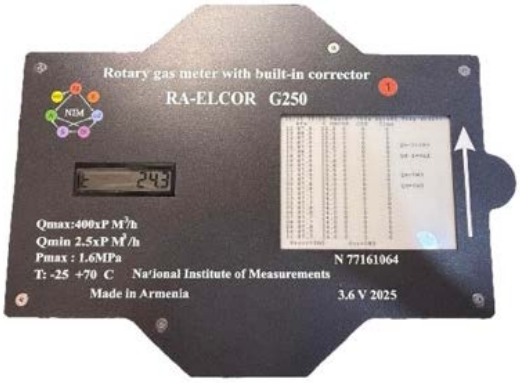

Fig. 3. RA ELCOR (G16 – G400) rotary flow meter screens

The built-in software of the RA ELCOR (G16 – G400) rotary meter brings the measured gas volume to standard conditions, when connected to a computer, it decodes the device's programming date, which is entered in the passport, which in the event of third-party software interference will not match the passport and computer data, as well as ensures a high degree of meter protection and records the following cases of external interference:

- in case of disassembly of the body, the message "Unauthorized operation. Disassembly" will appear on the meter screen (Fig. 4). It is not possible to restore the normal operation of the screen, the restoration is carried out only by the manufacturer,

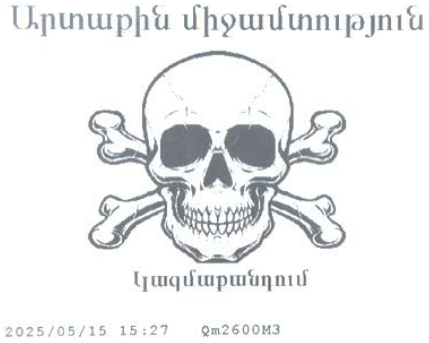

Fig. 4. RA ELCOR (G16 – G400) rotary flow meter external interference message

- in case of exposure to a magnetic field, it is also displayed on the screen as "Unauthorized operation. Magnetic field". It is not possible to restore the normal operation of the screen, restoration is carried out only by the manufacturer,

- if the meter rotors stop as a result of the intervention, this is recorded by the corresponding sensor and displayed on the screen as "Unauthorized operation. Rotors stopped". It is not possible to restore the normal operation of the screen, the restoration is carried out only by the manufacturer,
- the meter measures the temperature of the gas, as well as the ambient temperature. When the difference between these temperatures exceeds 20 degrees, it is displayed on the screen as "Unauthorized operation. Sudden change in temperature". It is not possible to restore the normal operation of the screen, the restoration is carried out only by the manufacturer.

Conclusion

The widespread use of the above-discussed and proposed RA ELCOR (G16 – G400) rotary flow meter, at least in the areas of legal metrological control, will contribute to the correct and comparable determination of gas consumption throughout the gas transportation and gas supply system, transparency of energy resource calculations, preparation of gas balances and control over the rational and efficient use of gas, and its use throughout the gas transportation and gas supply system will lead to an increase in the level of ensuring the uniformity of measurements.

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7. ՀՀ Հանրային ծառայությունները կարգավորող հանձնաժողովի N 536-Ն առ 14.12.2022թ որոշում:

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ԳԱԶԱՓՈԽԱԴՐՄԱՆ ԵՎ ԳԱԶԱԲԱՇԽՄԱՆ ՀԱՄԱԿԱՐԳՈՒՄ ԾԱԽՍԱՉԱՓՈՒԹՅԱՆ ՀԻՄՆԱԽՆԴԻՐՆԵՐԸ ԵՎ ԱՌԱՋԱՐԿՎՈՂ ԼՈՒԾՈՒՄՆԵՐԸ

Ա.Վ. Սահակյան, Ս.Մ. Էգնատոսյան

Ծախսաչափությունը չափագիտության ճյուղերից մեկն է, որը վերաբերում է որոշակի պայմաններում խողովակաշարով կամ համակարգով անցնող միջավայրի (գազ, հեղուկ կամ գոլորշի) քանակական որոշմանը: Առհասարակ չափագիտությունը գազափոխադրման և գազաբաշխման համակարգում հանդիսանում է հիմնասյուն, որի ճիշտ աշխատանքը նպաստում է գազի հաշվառմանը, կորուստների հաշվարկմանը, արտադրական ծախսերի նվազեցմանը, ինչպես նաև շրջակա միջավայրի վրա ազդեցության ճշգրիտ գնահատմանը և սպառողի ու աշխատակցի անվտանգության պաշտպանությանը: Բացի այդ, չմոռանանք Լորդ Կելվինի ասույթը. «Եթե դու դա չես կարող չափել, հետևապես՝ այն չես կարող ուղղել»:

Գազափոխադրման ողջ համակարգում գազի ծախսի ճիշտ և համեմատելի որոշումը նպաստում է էներգառեսուրսների հաշվարկների թափանցիկությանը և դրանց իրական խնայողության հնարավորություն է տալիս, քանի որ էներգախնայողության միջոցառումների ազդեցության քանակական գնահատումն է թույլ տալիս՝ որոշելու էներգիայի ռեսուրսների կորուստը աղբյուրից մինչև սպառող ճանապարհին: Բացի այդ, գազի սպառման որոշումը կարևոր է բնական գազի մատակարարի և սպառողի միջև առևտրային ճիշտ հարաբերություններ ստեղծելու համար, ինչպես նաև գազամատակարարման և փոխադրման եղանակների օպտիմալ կառավարման վերլուծության, գազափոխադրման և գազաբաշխման համակարգերում գազի հաշվեկշիռ կազմելու և գազի ռացիոնալ և արդյունավետ օգտագործման նկատմամբ վերահսկողություն իրականացնելու համար:

Գազն ունի որոշակի ֆիզիկաքիմիական հատկություններ և դրա քանակն ու ծավալը խիստ կախված են միջավայրային պայմաններից և այն մեծություններից, որոնք կարող են ազդել չափումների գործընթացի վրա: Գազափոխադրման և գազամատակարարման համակարգում իրականացվող չափումների միասնականություն ապահովելու և գազի ծախսի չափված ծավալները համեմատելի դարձնելու նպատակով չափված ծախսը պետք է հանգեցվի ստանդարտ պայմանների, քանի որ գազափոխադրման համակարգում գազի ծախսը չափվում է տարբեր ջերմաստիճաններում և ճնշումներում, հետևաբար՝ նաև տարբեր խտություններով:

Առանցքային բառեր. չափագիտություն, հոսքաչափ, չափման գործիք, չափման մեթոդ, չափման սկզբունք:

ОСНОВНЫЕ ПРОБЛЕМЫ РАСХОДОМЕТРИИ В СИСТЕМЕ ТРАНСПОРТИРОВКИ И РАСПРЕДЕЛЕНИЯ ГАЗА И ПРЕДЛАГАЕМЫЕ ПУТИ ИХ РЕШЕНИЯ

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Расходометрия – это раздел метрологии, занимающийся количественным определением расхода среды (газа, жидкости или пара), проходящей через трубопровод или систему при определенных условиях. В целом метрология является неотъемлемой частью системы транспортировки и распределения газа, правильное функционирование которой способствует учёту газа, расчёту потерь, снижению себестоимости продукции, а также точной оценке воздействия на окружающую среду и защите потребителей и сотрудников. Кроме того, не стоит забывать слова лорда Кельвина: «Если вы не можете это измерить, вы не можете это исправить».

Правильное и сопоставимое определение расхода газа в газотранспортной системе способствует прозрачности расчётов энергоресурсов и позволяет добиться их реальной экономии, поскольку количественная оценка влияния энергосберегающих мероприятий дает возможность определить потери энергоресурсов на пути от источника к потребителю. Кроме того, определение расхода газа важно для установления корректных коммерческих отношений между поставщиком и потребителем природного газа, а также для анализа оптимального управления режимами поставки и транспортировки газа, составления газового баланса в системах транспортировки и распределения газа и контроля за рациональным и эффективным использованием газа.

Газ обладает определенными физико-химическими свойствами, а его количество и объем существенно зависят от условий окружающей среды и от величин, которые могут влиять на процесс измерения. Кроме того, для обеспечения единства измерений, проводимых в системе транспортировки и газоснабжения газа, и сопоставимости измеренных объемов расхода газа измеряемый расход должен быть приведен к стандартным условиям, поскольку в системе транспортировки газа расход газа измеряется при разных температурах и давлениях, а следовательно, и при разных плотностях.

Ключевые слова: метрология, расходомер, измерительный прибор, метод измерения, принцип измерения.