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Technical aspects of natural gas energy metering implementation

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Abstract

In modern conditions, the issue of the quality of natural gas, including the development of gas energy measuring instruments, is becoming increasingly relevant. The Law of Ukraine "On the natural gas market" establishes the need for instrumental metering of natural gas "in order to obtain and register reliable information about the volumes and quality of natural gas during its transportation, distribution, supply, storage and consumption".

In accordance with the "Rules of natural gas supply" in force in Ukraine, settlements with consumers for natural gas should be carried out in cubic meters, reduced to standard conditions and expressed in energy units. However, this contradicts the requirement of the "Technical Regulations on measuring instruments", which state that settlements with consumers should be based on the results of measuring gas volumes read from the indicating device. However, the indicating devices of gas meters that are operated in Ukraine reflect the measured volumes of gas in cubic meters.

Currently, the requirements of the above regulatory documents are partially implemented, in particular, in full-scale industry and partly in the municipal sphere, the readings of measuring the volume of gas by the meters are being adjusted depending on the temperature and pressure of the gas.

The purpose of this work is to assess the regulatory requirements and technical possibilities of introducing natural gas metering in energy units in Ukraine.

It is proposed to use energy conversion devices to determine the energy of natural gas. A methodology has been developed for measuring natural gas energy by indirect methods based on measurements of the consumed gas volumes, air temperature around the gas meter and the results of measuring the calorific value of gas. The assessment of the metrological characteristics of the indirect measurement of natural gas energy has been carried out.

Keywords: natural gas; energy; volume conversion device.

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Introduction

The issue of the quality of natural gas is closely related to its energy performance. Currently, gas metering is carried out in cubic meters and, more than ever, the issue of developing gas energy measuring instruments is urgent. The current regulatory documents regulate the need to introduce natural gas metering in energy units in Ukraine [1]. The Law of Ukraine "On the natural gas market" [2] establishes the need for metering natural gas "in order to obtain and register reliable information on the volume and quality of natural gas during its transportation, distribution, supply, storage and consumption".

In accordance with the current in Ukraine "Rules of natural gas supply" [3], settlement with consumers for natural gas must be carried out in cubic meters, reduced to standard conditions and expressed in energy units. However, this is contradicted by the requirement of the "Technical Regulations on measuring instruments" [4], which states that settlements with consumers should be carried out on the basis of the results of measuring gas volumes read from the indicating device. As it is known, indicating devices of gas meters, which are operated in Ukraine, reflect the measured volumes of gas in cubic meters.

The purpose of this work is to assess the regulatory requirements and technical possibilities of introducing natural gas metering in energy units in Ukraine.

Methods and technical means for determining the energy of natural gas

Before natural gas is supplied to end users, the gas volume and its physical and chemical parameters are measured at the gas flow measurement points, the components of which are:

- gas volume meters;
- gas volume calculators.

The volume of energy of natural gas passing through a commercial gas metering unit (GMU), which is located on a route that is equipped with flow metering devices (FMD) for determining the physical and chemical parameters (FCP) of gas, according to [5], can be determined:

- in automatic mode using correctors or gas volume calculators with the function of calculating the energy of natural gas, which receive data directly from the streaming FMDs for determining the FCP of gas;
- in semi-automatic mode using specialized programs based on average values of the calorific value per hour from streaming FMDs for determining the FCP of gas and gas volume per hour from gas volume correctors / calculators.

The amount of energy of natural gas passing through commercial GMU, which is located on the route where the determination of FCP gas is carried out using measuring chemical analytical laboratories, according to [5], can be determined:

- in a semi-automatic mode using correctors or gas volume calculators with the function of calculating the energy of natural gas based on the value of the gross calorific value, which is entered in the calculator / corrector using specialized programs as a conditionally constant parameter, and the gas volume for the calculation period;
- in semiautomatic mode using specialized programs based on the value of the gross calorific value, equal to the last determined value of the gross calorific value and gas volume per hour from gas volume correctors / calculators.

In the public utilities sector, gas volume correctors and calculators have not found application due to their long payback period. Only partially household gas meters are equipped with gas temperature correction devices. Therefore, the use of existing measuring instruments, without their modernization, makes it impossible to carry out gas metering (in the domestic sphere) in energy units.

Technical regulations [4] allow for gas metering to use volume conversion devices. It is the replenishment of gas meters with devices for converting the measured volume of natural gas into energy that can be a way out of the situation.

The operation algorithm of such devices is as follows.

Total energy value E_t, according to [6], calculate by time interval t by the following formula:

$$E_t = E_{t-1} + \Delta E_t, \tag{1}$$

where E_{t-1} – total value of energy over time interval, t.

Determination of energy gain ΔE_t , according to [6], is carried out by summing up the untranslated volume V_i:

$$\Delta E_t = K\left(H_s\right)_t \sum_{i=1}^{k} V_i, \tag{2}$$

where

$$K = \frac{T_b}{T}\frac{P}{P_b}, \tag{3}$$

where K – a constant typical for the conversion factor, which is used to convert the sum of the volume gain V_i under measurement conditions up to volumetric gain under standard conditions; T, P – measured values of temperature and pressure of natural gas; T_b – natural gas temperature value at standard conditions, which is equal to 273.15 K or 288.15 K, depending on the individual characteristics and the place of installation of the gas meter (outdoors or indoors); P_b =101325 Pa – natural gas pressure value at standard conditions; $\left(H_s\right)_t$ – value of the calorific value of gas for the summation period t.

An alternative method for determining the volumes of natural gas counted by the meters, taking into account the specific differences in gas volumes, is given in [7].

The value of the calorific value is given monthly by gas supplying organizations in payment documents for each consumer of natural gas. It is not economically feasible to measure gas pressure, since pressure measuring instruments are several times more expensive than gas meters and have a significant payback period. In [8] the calculation method for determining the pressure of natural gas is given, which is taken into account in the domestic sphere. Gas pressure components are atmospheric (barometric) and overpressure:

$$P = P_{\text{a}} + P_{\text{H}}, \tag{4}$$

where

$$P_{\text{a}} = 101578 - 11.532h, \tag{5}$$

where h – the geographical height of the measurement point (settlement) above sea level, given in [8]; P_{H}= 3000 Pa – overpressure of gas for domestic gas pipelines, in accordance with [9].

Taking this into account, formula (5) will be written in the following form:

$$P_{\text{a}} = 101578 - 11.532h + 3000 = 104578 - 11.532h. \tag{6}$$

Another measuring parameter in formula (3) is gas temperature. Retrofitting the conversion device with a temperature sensor requires an additional tie-in into the gas pipeline, which is costly and explosive. There are two ways to deal with this situation. The first is the use of gas meters with thermal compensation devices, the second is the use of a thermal compensator [10], the installation of which does not require a tie-in into the gas pipeline. Then the gas temperature T will be equal to the air temperature around the meter T_{HC}:

$$T = T_{\text{HC}}. \tag{7}$$

Taking into account formulas (6) and (7), formula (3) will be written in the following form:

$$\begin{aligned} K &= \frac{T_b}{T_{\text{HC}}} \frac{104578 - 11.532h}{101325} = \\ &= \frac{T_b}{T_{\text{HC}}} \left(1.0321 - 1.13812 \cdot 10^{-4} h\right), \end{aligned} \tag{8}$$

and formula (2) takes the form:

$$E_t = E_{t-1} + \frac{T_b}{T_{\text{HC}}} \cdot \left(1.0321 - 1.13812 \cdot 10^{-4} h\right) \cdot \left(H_s\right)_t \cdot \sum_{i=1}^{k} V_i. \tag{9}$$

Equation (9) makes it possible to determine the energy of natural gas based on the data on the calorific value of gas, the geographical altitude of the measuring point above sea level and the readings of the gas meter without the need for additional measurements of gas temperature and pressure.

Metrological analysis of natural gas energy determination

A unit increase in energy, based on equation (9), is:

$$E_t = \frac{T_b}{T_{\text{HC}}} \cdot \left(1.0321 - 1.13812 \cdot 10^{-4} h\right) \cdot H_s \cdot V. \tag{10}$$

Let us estimate the error in determining the energy of natural gas by the formula (10). Since the measurements are indirect, then in accordance with the requirements of [11], we have to determine the root mean square deviation (RMS) S_{E_t} of the results of indirect measurements, which is determined as follows:

$$S_{E_t} = \sqrt{\left(\frac{\partial E_t}{\partial T_{\text{HC}}}\right)^2 \cdot S^2_{T_{\text{HC}}} + \left(\frac{\partial E_t}{\partial H_s}\right)^2 \cdot S^2_{H_s} + \left(\frac{\partial E_t}{\partial V}\right)^2 \cdot S^2_V}, \tag{11}$$

where $S_{T_{\text{HC}}}$, S_{H_s}, S_V – RMS of the results of air temperature measurements T_{HC}, heat of combustion H_s and volume of natural gas V, in accordance;

$\frac{\partial E_t}{\partial T_{\text{HC}}}$, $\frac{\partial E_t}{\partial H_s}$, $\frac{\partial E_t}{\partial V}$ – influence coefficients, which are derivatives of natural gas energy by variables T_{HC}, H_s, V, are presented as:

$$\frac{\partial E_t}{\partial T_{\text{HC}}} = -\frac{T_b}{T^2_{\text{HC}}} \cdot \left(1.0321 - 1.13812 \cdot 10^{-4} h\right) \cdot H_s \cdot V, \tag{12}$$

$$\frac{\partial E_t}{\partial H_s} = \frac{T_b}{T_{\text{HC}}} \cdot \left(1.0321 - 1.13812 \cdot 10^{-4} h\right) \cdot V, \tag{13}$$

$$\frac{\partial E_t}{\partial V} = \frac{T_b}{T_{\text{HC}}} \cdot \left(1.0321 - 1.13812 \cdot 10^{-4} h\right) \cdot H_s. \tag{14}$$

The confidence limits of the random component of the relative error in measuring the energy of natural gas are calculated by the formula given in [11]:

$$\delta_{E_t} = \pm t_q \cdot \frac{S_\Sigma}{E_t} \cdot 100\%, \tag{15}$$

where t_q is the Student's coefficient determined in accordance with [11].

Maximum permissible error of natural gas energy measurement δ_{E_t}, in accordance with [6], is: in the case of retrofitting energy conversion devices for gas meters of class A – ±1.0%, class B – ±2.0%, class C – ±2.5%.

The introduction of the proposed method will allow the creation of a unified energy accounting system [12, 13].

Conclusions

Based on the results of the assessment of regulatory requirements and technical possibilities of introducing natural gas metering in energy units in Ukraine, a methodology for measuring natural gas energy by indirect methods was developed based on measurements of consumed gas volumes, air temperature around the gas meter and the results of measuring the calorific value of gas.

The subject of further scientific research will be the development of a unified energy accounting system, an element of which will be an energy conversion device, and an experimental study of the technical and metrological characteristics of this system.

Технічні аспекти реалізації обліку енергії природного газу

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Анотація

Наразі все актуальнішим є питання якості природного газу, в тому числі й розробки засобів вимірювань енергії газу. У Законі України "Про ринок природного газу" встановлюється необхідність приладового обліку природного газу "з метою отримання та реєстрації достовірної інформації про обсяги і якість природного газу під час його транспортування, розподілу, постачання, зберігання та споживання".

Відповідно до "Правил постачання природного газу" розрахунок зі споживачами за природний газ повинен здійснюватися в метрах кубічних, приведених до стандартних умов і виражених в енергетичних одиницях. Але цьому суперечить "Технічний регламент засобів вимірювальної техніки", який стверджує, що розрахунки зі споживачами необхідно здійснювати на основі результатів вимірювання об'ємів газу, зчитуваних із показувального пристрою. Однак показувальні пристрої лічильників газу, що експлуатуються в Україні, відображають виміряні об'єми газу в метрах кубічних.

Станом на сьогодні частково реалізовано вимоги вищенаведених нормативно-правових документів, зокрема, повною мірою в промисловості й частково в комунально-побутовій сфері здійснюється коригування показів вимірювання об'єму газу лічильниками залежно від температури і тиску газу.

Метою роботи є оцінка нормативно-правових вимог та технічних можливостей впровадження в Україні обліку природного газу в одиницях енергії.

Запропоновано для визначення енергії природного газу використовувати пристрої перетворення енергії. Розроблено методологію вимірювання непрямими методами енергії природного газу на основі вимірювань спожитих об'ємів газу, температури повітря навколо лічильника газу та результатів вимірювання теплоти згоряння газу. Здійснено оцінку метрологічних характеристик опосередкованого вимірювання енергії природного газу.

Ключові слова: природний газ; енергія; пристрій перетворення об'єму.

Технические аспекты реализации учета энергии природного газа

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Аннотация

В настоящее время все более актуальным является вопрос качества природного газа, в том числе и разработки средств измерений энергии газа. В Законе Украины "О рынке природного газа" устанавливается необходимость приборного учета природного газа "с целью получения и регистрации достоверной информации об объемах и качестве природного газа при его транспортировке, распределении, поставке, хранении и потреблении".

Целью работы является оценка нормативно-правовых требований и технических возможностей внедрения в Украине учета природного газа в единицах энергии.

Предложено для определения энергии природного газа использовать устройства преобразования энергии. Разработана методология измерения косвенными методами энергии природного газа на основе измерений потребленных объемов газа, температуры воздуха вокруг счетчика газа и результатов измерения теплоты сгорания газа. Осуществлена оценка метрологических характеристик косвенного измерения энергии природного газа.

Ключевые слова: природный газ; энергия; устройство преобразования объема.

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