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Procedure of hydrogen and mixture impact assessment on the changes of mechanical parameters and errors of household gas meters

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Abstract

The article describes the method of conducting representative research to determine the effect of pure gaseous hydrogen and a mixture of hydrogen and natural gas (methane) on the performance and metrological characteristics of household gas meters. The experimental research has been carried out in two stages. 84 membrane and rotary meters have been selected for research. The main aspect of the need for such research is the safety of meters. Before the start of the tests and after each stage, the metrological characteristics of all gas meters on the reference prover are determined. At the first stage, a set of static tests is performed, according to which the internal and external short-term and long-term (42 days) tightness of gas meters are checked. A prototype of the installation layout has been developed to conduct experiments on determining the tightness. The second stage is to conduct a dynamic series of tests. Gas meters are assembled according to the developed scheme and installed for testing on the model of the gas distribution network system. It is recommended to use a drum-type meter as a reference gas meter. The criterion for determining the effect of hydrogen and gas meter is the established change in metrological characteristics after the study.

Keywords: gas meter; hydrogen; mixture; metrological characteristics.

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Introduction

As part of the practical implementation of the European Hydrogen Strategy [1], the Government and the Commission of the European Union have identified Ukraine as one of the priority partners in the supply of hydrogen to Europe. To this end, Gas Transmission System Operator of Ukraine LLC has joined the European Pure Hydrogen Alliance, which in turn is a key element of the hydrogen strategy, together with other natural gas transportation market operators in the European Union. The implementation of the strategy envisages a gradual transition to hydrogen energy and, accordingly, a reduction of CO_2 emissions. In fact, there is a declared desire to reduce the impact of industry (its negative effect) on the world climate, in other words, to application the principle of climate-neutral economy within Europe with the hope that this initiative will extend to the world economy. It should be added that the implementation of the Hydrogen Strategy is an integral part of the European Green Agreement [2].

In Ukraine, a scientific and practical working group was established to study and the possibility of production, transportation and consumption of pure hydrogen and / or its mixture with natural gas, which included leading organizations interested in the project, such as: Gas Institute, Electric Welding Institute, Institute of Coal Energy Technologies and Institute of Physics and Mechanics of the National Academy of Sciences of Ukraine, Lviv Polytechnic National University, Ivano-Frankivsk National University of Oil and Gas, SE "Ivano-Frankivskstandardmetrology", Regional Gas Company (RGC), Naftogazbudinformatyka LTD [3]. Each of the participants received a clearly defined direction for the implementation of representative theoretical and applied studies of the impact of hydrogen on the elements and materials of the gas transmission and distribution networks in Ukraine.

Currently, in the conditions of the prototype model of the medium and low pressure gas distribution system (test fill) of the Gas Distribution Networks (GDN) operator, RGC specialists conducted a series of fifteen experiments filling hydrogen gas piping system to determine the tightness of binding pipeline networks under pure hydrogen. Static tests were conducted at five RGC test fills in Kharkiv, Dnipropetrovsk, Ivano-

Frankivsk, Zhytomyr and Volyn regions. The results presented studies indicate that the pipeline network is not sealed when filling clean gaseous hydrogen [4].

SE "Ivano-Frankivskstandartmetrology" as a scientific metrological center is engaged in conducting a set of experimental studies to research and detect the effects of pure hydrogen gas and mixtures of hydrogen with natural gas (methane) with different concentrations of gas meters used in the domestic sector. A series of such studies is needed to establish the possibility of determining the volume of hydrogen mixture under the condition of supply and, accordingly, its transportation in the domestic pipeline system for use (combustion) in gas appliances by consumers.

The objective of this article is to develop and practical application of methodology for determining the impact of pure hydrogen and mixtures of hydrogen with natural gas (methane) on the performance and metrological characteristics of gas meters used in the domestic sector.

In developing the methodology of research, the authors pursued two main aspects: the first is safety and the second is metrology proper. In terms of safety, in this case, this issue is related to the safe use of the gas meter when accounting for a hydrogen mixture. That is, this stage of experiments is necessary to check the external and internal short-term and long-term tightness of the housing and elements of the meter for the presence of hydrogen leaks.

In accordance with the developed methodology, representative studies are conducted to determine the effect of hydrogen and / or mixtures of natural gas with hydrogen on the operation of gas meters, namely, two stages of experiments: static tests and dynamic tests.

Before the beginning of experimental researches and after completion of each stage (static and dynamic tests) of experiment, according to the developed methodology, first definition, and then control of change of metrological characteristics of meters in laboratory conditions with working environment – air.

Specialists of SE "Ivano-Frankivskstandartmetrology" together with RGC determined the recommended list of gas meters used in the household sector. The priority choice was membrane and rotor meters of different manufacturers, in addition, no less important criterion was the year of manufacture of the meter. This feature is due to the fact that in Ukraine for gas accounting in the home in some places still used gas meters produced in 1995 and later. A total of 84 gas meters were selected for the experiments: 78 pieces of membrane type, 6 pieces of rotor type. In particular, membrane-type meters of the following manufacturers present in Ukraine were selected: Elster (BK meter), Itron, Schlumberger (Gallus meter), Metrix (Metrix meter), Vizar plant (BP and Vizar meters), Generator plant (Octava meter), Samgaz plant (Samgaz meters) and rotor meters of manufacturers: Yampil Instrument-Making Plant (RL meter), Novator plant (RL meter). Selected meters with size G 2.5–G 4 with an extended measuring range and, accordingly, the value of the minimum flow $Q_{min} = 0.016$ m^3/h, the year of production of meters is from 1995 to 2020.

An initial research metrological characteristic of the meters was conducted using Universal prover for research of gas meters (calibration certificate number 260K-04/20 of 28.12.2020). The expanded uncertainty of measurement by the prover does not exceed 0.2%. Experimental studies were performed in the laboratory at a temperature of (20 ± 2) °C.

A series of three repeated measurements was performed for each meter with the following values of volume flow: Q_{max}, 0.7 Q_{max}, 0.5 Q_{max}, 0.25 Q_{max}, 0.1 Q_{max}, Q_{min}. Since all meters are selected for the experiment after operating conditions, it is advisable to apply metrological requirements for errors in accordance with the normative document R 50-071-98 [5], ie (±3)% (in the range of volume flow rate from Q_{max} to Q_t inclusive) and (+3 ÷ –6)% (in the range of volume flow rate from Q_t to Q_{min}).

From 84 meters that were tested, the following results of metrological characteristics were obtained: 60 meters – the relative error does not exceed the permissible limits; 20 meters – the relative error exceeds the permissible limits slightly; 4 meters – the relative error in the flow Q_{min} is (–100)%.

Regarding the possibility of further use of gas meters and suitability for operation with an error value (–100%), then, from the point of view of legal metrology, it is impossible. However, it was decided to leave them for further experiments in order to establish changes in metrological characteristics after performing the entire list of experiments and the impact of pure hydrogen and gas-hydrogen mixtures.

After determining the primary values of metrological characteristics of the studied meters, we conduct the first stage of static tests. This stage consists in checking the tightness of the meter housing and, accordingly, detecting the effect of hydrogen and mixtures of hydrogen with natural gas (methane) on the material from which the meters are made. Static tests are performed by checking the external tightness of the meters when filling the meter housing with hydrogen and mixtures with a value of excess pressure, which is the maximum for meters of the domestic sector (according to DSTU EN 1359 [6], the maximum operating pressure is 50 kPa). Hydrogen and / or a mixture is gradually fed into the measuring chamber of the meters from the pressure source. The value of excess pressure is given in the operating documents on the meters, but must be not less than 1.5 P_{robmax}, i.e. 75 kPa excess pressure.

To conduct a series of static experiments, an experimental model of a prototype test system for the tightness of gas meters under the action of hydrogen gas was developed (Fig. 1). The model is necessary

Fig. 1. Experimental model of a prototype test system for the tightness of gas meters under the action of hydrogen gas

for a preliminary assessment of the possibility of using sealing materials of different types to ensure tightness.

The next step is to detect the effect of hydrogen on the material from which the membranes / rotors and other components of the meter are made, in direct contact with the gas. This stage of experiments is to detect the effect of hydrogen and mixtures in direct contact with the materials from which the meters are made and which constructively interact with it during the accounting (measuring membranes, sliding mechanism, rotor pairs, etc.).

The stage is carried out in the mode of setting the maximum value of excess pressure in the meter, which is allowed according to DBN B.2.5-20:2018 Gas supply (not more than 3 kPa) [7] or with the value of pressure that is recommended for gas appliances (gas stoves, columns), boilers), usually 1.1–1.3 kPa. The tests are carried out similarly, filling the meter housing with hydrogen and mixtures of hydrogen with natural gas, with periodic monitoring of the values of excess pressure every 24 hours. The tests are performed for 42 days. The criterion for assessing the effect of hydrogen on the gas meters is the difference between the relative measurement errors before and after the experiments, the determination of which is carried out in the laboratory.

After carrying out a complex of static tests, carry out dynamic tests in the conditions of a prototype of the model of gas distribution system of average and low pressure of the GDN operator.

Dynamic tests are conducted in two successive stages:

1. Repeated, after conducting static tests, the research of metrological characteristics in the laboratory.

2. Research of metrological characteristics in the conditions that maximally reproduce the use of meters on the site of the layout of the gas distribution system of the GDN operator.

Test 1. At the first stage of dynamic tests, the determination of metrological characteristics (calibration characteristics) of gas meters in the laboratory with the working environment – air at a pressure close to atmospheric.

Test 2. Installation of the measuring system in the conditions of the experimental site of the layout of the gas distribution system is carried out by installing successively on one pipeline different types of meters (membrane, rotor types), shown in the scheme of installing meters on the simulation site (Fig. 2). Before conducting experiments, the assembled circuit must be purged with inert gas (nitrogen or other) in accordance with the Safety Rules [8].

The experiment is carried out using hydrogen and mixtures of natural gas (methane) with hydrogen as a working medium. The following concentrations of components are provided: a) 100% (H_2); b) 20% (H_2)/ 80% (CH_4); c) 10% (H_2) / 90% (CH_4).

As a reference meter, it is recommended to use a drum-type gas meter with a predetermined calibration characteristic in laboratory conditions with a working medium – air. Drum-type gas meter with water valve to meet safety requirements is installed in the measuring system after the experimental meters to reduce the effects of evaporation and saturation of hydrogen with water vapor. To establish and regulate a stable value of the volumetric flow rate of hydrogen, rotameter is used. Before the start of the experiment, it is necessary to record the value of gas volumes according to the readings of the reading devices of gas meters. Start the process of measuring the volume of the gas by setting the required value of the volumetric flow rate of 0.25 Q_{max} from the value of the maximum flow rate. The volume of hydrogen and mixture to be passed through the meters must be at least 0.1 m^3.

At the end of the test cycle, for the tested meters and the reference meter it is necessary to re-determine in the laboratory their metrological characteristics in order to establish their change under the influence of pure hydrogen.

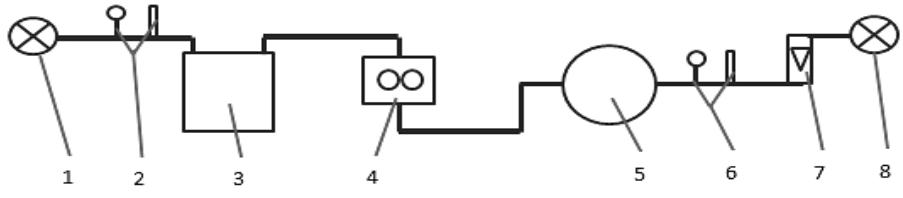

Fig. 2. Scheme of installation of meters on the site of the layout of the gas distribution system (simulation site): 1, 8 – valves; 2, 7 – sensors; 3 – membrane gas meter; 4 – rotor gas meter; 5 – drum gas meter; 7 – rotameter

Conclusion

In order to conduct a set of representative studies, developed and approved in the prescribed manner RMU 001 RD/M-2021 "Recommendation. Metrology. Gas meters. Methodology for determining the impact of pure hydrogen and mixtures on performance and metrological characteristics of gas meters used in the domestic sector", according to which a series experiments will do.

Процедура оцінки впливу водню та сумішей на зміну механічних параметрів і похибок побутових лічильників газу

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Анотація

У статті описано методику проведення репрезентативних досліджень щодо визначення впливу чистого газоподібного водню та суміші водню з природним газом (метаном) на працездатність та метрологічні характеристики побутових лічильників газу. Проведення експериментальних досліджень передбачено в два етапи. Для проведення досліджень відібрано 84 лічильники мембранного та роторного типів. Основним аспектом необхідності проведення таких досліджень є питання безпеки лічильників при обліку газоводневої суміші. Перед початком проведення випробувань та після кожного етапу визначають метрологічні характеристики усіх лічильників газу на еталонній установці в лабораторних умовах. На першому етапі проводиться комплекс статичних випробувань, відповідно до яких здійснюється перевірка внутрішньої та зовнішньої короткотермінової і довготермінової (42 дні) герметичності лічильників газу та його внутрішніх елементів (мембран, роторних пар), які контактують із газом. Для проведення експериментів на визначення герметичності розроблено прототип макету установки. Другий етап полягає у проведенні динамічної серії випробувань. Лічильники газу та під'єднувальні трубопроводи збираються відповідно до розробленої схеми і встановлюються для проведення випробувань на макеті системи газорозподільчих мереж. Як еталонний лічильник газу рекомендовано застосувати лічильник барабанного типу з водяним затвором. Для виставлення значення об'ємної витрати газу доцільно застосувати ротаметр. Дослідження проводяться на трьох типах сумішей, на чистому водні та на суміші водню з природним газом (метаном) із різною пропорцією концентрації. Критерієм визначення впливу водню на лічильник газу є встановлена зміна метрологічних характеристик після проведення досліджень. Для проведення комплексу вказаних досліджень розроблено та затверджено методичний документ.

Ключові слова: лічильник газу; водень; суміш; метрологічні характеристики.

Процедура оценки воздействия водорода и смеси на изменение механических параметров и погрешностей бытовых счетчиков газа

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Аннотация

Описана методика проведения исследований по определению влияния водорода и смеси водорода с природным газом на работоспособность и метрологические характеристики бытовых счетчиков газа. Проведение исследований предусмотрено в два этапа. Для проведения исследований отобрано 84 счетчика. Основным аспектом необходимости

проведения таких исследований является вопрос безопасности счетчиков. Перед началом проведения испытаний и после каждого этапа определяют метрологические характеристики счетчиков газа на эталонной установке. На первом этапе проводится комплекс статических испытаний, согласно которым осуществляется проверка герметичности счетчиков газа. Для проведения экспериментов на определение герметичности разработан прототип макета установки. Второй этап заключается в проведении динамических испытаний. Счетчики газа собираются в соответствии с разработанной схемой и устанавливаются на макете системы газораспределительных сетей. В качестве эталона рекомендуется применить счетчик барабанного типа. Исследования проводятся на трех типах смесей. Критерием определения влияния водорода на счетчик является изменение метрологических характеристик.

Ключевые слова: счетчик газа; водород; смесь; метрологические характеристики.

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