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Qualimetric assessment of metrological characteristics of household gas meters during periodic verification

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Abstract

Informative parameters for statistical estimation of operational error of SAMGAS, METRIX, PREMAGAS household gas meters (HGM) are formulated. These are the values of the measured volume during the verification period of operation and the experimentally determined error of the meter during operation at three normalized flow rates: minimum, maximum and 20% of the maximum.

Six ranges of variation of the HGM error at the minimum flow rate were selected to form statistical samples of meters. According to the proposed algorithm, the change in the weighted average HGM error for three normalized flow rates from the measured volume is quantified, taking into account the number of HGMs and their error ranges. It is proposed to apply the concept of generalized weighted average error of HGM, which reflects the operational error of HGMs during their operation in the entire range of consumption when measuring gas volumes up to 60 thousand cubic meters.

Keywords: household gas meter; error; flow rate; metrological research; statistical estimates; weighted average error.

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1. Introduction

Household gas meters (HGM) are the well-known means of achieving rational and economical use of natural gas by household consumers and small private enterprises. They are characterized by appropriate technical and metrological characteristics. Among them, the most important for proper accounting is the error of the HGM, which directly affects the economical use of natural gas, as the growth of the error causes its losses. At the same time, a positive one causes an overpayment for its consumption (consumers lose), and a negative one leads to an underpayment for the consumed gas (gas supply organizations lose).

In real operating conditions of the HGM, the actual error of natural gas metering is almost impossible to determine, because it varies not only from operating costs, from the mode of gas consumption, but from many also operational factors, such as service life, quality of construction, volume of measured gas (intensity of operation), gas temperature and other factors. The so study of operational metrological characteristics of HGM is urgent task.

In the study of HGM it necessary to operate with statistical information, to calculate average or generalized indicators because the operation of HGM there is always a scatter of their measurement results due to the instability of metrological characteristics. For example in [1] the accuracy of natural gas metering under real temperature conditions of HGM operation is statistically investigated. The presence of negative errors in the operation of meters at negative temperatures is shown on the basis of the results of experimental studies of G4 model HGM. It established that the presence of an average minus error at an average gas temperature of -10 °C causes a gas metering error in Warsaw from -6.1% to -10.4%, and in Zakopane from -2.7% to -1.8%, on which affected by the average monthly gas temperature during the year.

Polish scientists [2] also studied the effect long duration of HGM operation under extreme operating conditions at ambient temperatures of -25 °C, +20 °C, +55 °C. The error of membrane meters after their 2000 hours of operation was determined. It is established that there is a significantly greater impact of high ambient temperatures compared to the impact of low temperatures, which is ambiguous at different operating consumption.

These publications do not study the change in the metrological characteristics of HGMs under the conditions of their statistical samples, which would involve the analysis of a large number of meters and the generalization of the patterns of change of the HGM error curves.

We conducted studies of changes in HGM error based on the results of their periodic calibration of meters after the end of the eight-year [3, 4]. Elaboration of the calibration results showed that there is a significant change in the error of the HGM during operation at the minimum operating consumption Q_{min}, there is an underestimation of natural gas. At the same time, the change in the error at the maximum cost and the cost is much smaller and practically does not correlate with the change in the error at. Errors for and mostly correspond to the allowable passport values.

We conducted studies of changes in HGM error based the results of periodic calibration of meters after the end of the eight-year [3, 4]. Elaboration of the calibration results showed that there is a significant change in the error of the HGM at the minimum operating consumption Q_{min}, there is an underestimation of natural gas. At the same time, the change in the error at the maximum consumption Q_{max} and the consumption is much smaller 0.2 Q_{max} and practically does not correlate with the change in the error at Q_{min}. Errors for Q_{max} and 0.2 Q_{max} mostly correspond to the allowable passport values.

The results of statistical methods of analysis of the change of HGM error, which corresponds to the allowable limits of meter calibration, allowed to metrological substantiate the new method of HGM calibration. It provides a calculation method for determining the error of the HGM for maximally work gas consumption [5].

Along with this, an unexplored aspect is the study of the influence of the value of the measured volume of natural gas by household meters on the change in the shape of the HGM error curve, their metrological characteristics. This analysis characterizes the intensity of operation of the HGM and can informatively serve not only as a criterion for the efficiency of the HGM, but also a factor in the quality of the design of the HGM by different manufacturers. Therefore, the operational characteristics of HGM must be evaluated using statistical information that allows them to be characterized for a certain way of formed samples of meters.

Main part

Experimentally established values of HGM errors [3] during operation at minimum consumption are characterized by a significant range of error changes, which can significantly exceed not only the allowable passport values (±3%), but also the allowable operating error (-6%). The real negative error in some HGM can increase to -30... -40% and even more. However, different ranges of error will correspond to specific ranges of error change. Therefore, in the statistical study of the metrological characteristics of HGM, it is necessary to take into account the weights that would take into account the number of HGM with specific ranges of operational error. This justifies the need for qualimetric estimation of HGM errors taking into account their statistical samples.

The results of calibration in 2018 of the most common in practical application models of HGM size G4 in the conditions of SE “Ivano-Frankivskgas” were selected for the study, among which productions SAMGAS (Rivne) – 3244, METRIX (Poland) – 1478, PREMAGAS (Slovakia) – 5483. The informative parameter for the analysis is the error of the HGM at the minimum consumption, which is most sensitive to changes in the metrological characteristics of the HGM, at which most household meters are not calibrated.

The following ranges of obtained HGM errors at this cost were selected for statistical analysis: 0...+3; 0...-3; -3...-6; -6...-9; -9...-15, -15...-30; HGM with an error of more than -30%, including those in which the reading device did not work were not taken into account. The range of errors (-3...+3)% characterizes the confirmation of the passport error of new HGM, and its expansion to minus 6% makes it possible to estimate the number of suitable for further operation of HGM without repair. In addition, three more ranges of HGM errors were formed, which in principle, in our opinion, are subject to repair. Meters with an error of more than minus 30% need major repairs, or it is advisable to replace them with another.

The obtained research results (Fig. 1) are presented by histograms of the distribution number of HGM (in percent) with the corresponding formed for analysis of operational errors of the HGM at the minimum consumption of different manufacturers.

Regularities of change of operational error of HGM, which characterize rather various regularities of change of stability of metrological characteristics of HGM at meters of manufacturers. The largest positive error at minimum operating costs is characterized by HGM model METRIX (35.2% of the total), which is quite unexpected according to modern scientific statements about the error of HGM at minimum consumption. At the same time, a positive error at these costs, but to a lesser extent, is typical for other models – SAMGAS (22.9%), PREMAGAS (8.18%).

Predictable and experimentally confirmed is the highest percentage of HGM with error (0...-3)%, the

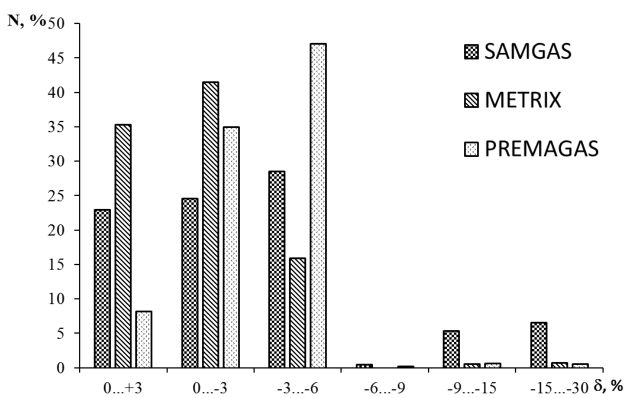

Fig. 1. Histograms of distribution operational error of the HGM different manufacturers

number of which is in the range of 25–43%. Along with this, the number of PREMAGAS meters (47.05%) with error (-3...-6)%, which are among the suitable for further operation, is significant. It is also possible to note a slightly larger number of SAMGAS meters with more significant errors (-9...-15)% - 5.36% and (-15...-30)% - 6.53% of the number of HGM.

At the same time, the histogram does not reflect the effect on the error of the intensity of HGM operation in the inter-calibration period, the value of the measured gas volumes. Therefore, samples of meters were formed for the volume of V measured natural gas for the inter-calibration period, which was selected with an interval of 10 thousand m^3 to the maximum value of the measured volume of 60 thousand m^3. Then, within each sample, groups of meters were formed with the following ranges of errors with a minimum operating consumption: 0...+3; 0...-3; -3...-6; -6...-9; -9...-15; -15...-30%. For example, SAMGAS HGM, the number of meters with a measured volume of up to 10 thousand m^3 according to the above six error ranges was 339; 277; 316; 6; 52; 62 respectively. In addition, for each group of meters, the arithmetic mean value of the error $\bar{\delta}_i$ at consumption $Q_{\min}$, 0.2 $Q_{\max}$, $Q_{\max}$ and the average value of the measured gas volume $\bar{V}_i$ were calculated.

The weighted average error (WAE) δ_{wmi} at the minimum operating cost $Q_{\min}$ HGM for the i-th range of the measured volume was calculated according to the algorithm:

$$\bar{\delta}_{wmi} = \sum_{j=1}^{l} \bar{\delta}_{Q_{\min ij}} \left(n_{ij} / N_i \right), \tag{1}$$

where $\bar{\delta}_{Q_{\min ij}}$ is the average value of the HGM error at the minimum flow rate for the i-th volume range of the j-th error range $N_i = \sum_{j=1}^{l} n_{ij}$, $\bar{V}_i = \frac{1}{l}\sum_{j=1}^{l} \bar{V}_{ij}$ (N_i is the number of meters for the i-th range of the measured volume, $\bar{V}_i$ is the average value of the measured volume for i-th range, j – the number of the selected range of HGM errors from the total – l).

Similar calculations for the other i-th ranges of the measured volume allowed to obtain the dependences of the change in the average error of the WAE on the measured volume of gas (Fig. 2).

The established regularities have shown that the WAE in all studied models of HGM at minimal cost increases with increasing volume of measured gas. In all models of HGM, the error is negative and is in the range from -1 to -6%, ie does not exceed - 6%. PREMAGAS HGM are characterized by the smallest quantitative increase of WAE (about 0.11%) per 10 thousand m^3, they have the best stability of error when increasing the measured volume. The increase in negative error for SAMGAS and METRIX is slightly larger and is about 0.45%, 0.21%, respectively.

The study of WAE at the maximum operating cost for all these models of HGM showed that it is in the range from - 0.8% to +0.3%, but the patterns of its change with increasing measured volume are not found, illustrating Fig. 2*b*.

Since the established patterns do not allow to determine the change in operational error of the HGM taking into account the entire range of work, it is advisable to use a generalized indicator that will characterize the full-range generalized WAE of meter samples taking into account the error at three consumption. To record the algorithm for determining such WAE, we use the formula from the normative document [6], which we use not for a single meter, but for the statistical samples generated by us.

The specified algorithm for calculating the generalized WAE takes the form:

$$\bar{\delta}_{wm} = \sum_{p=1}^{s} k_p \bar{\delta}_{wmp} \Big/ \sum_{p=1}^{s} k_p , \tag{2}$$

where $\bar{\delta}_{wmp}$ – WAE for the p operating flow of the HGM, k_p – weighting factor, which is defined as $k_p = Q_p / Q_{\max}$ at $Q \le 0.7\,Q_{\max}$ and $k_p = 1.4 - \left(Q_p / Q_{\max} \right)$ at $0.7\,Q_{\max} \le Q \le Q_{\max}$.

Taking into account the range of operating costs HGM 1: 150 and the three studied costs, formula (2) will be written:

$$\bar{\delta}_{wm} = 0.0067\left(\bar{\delta}_{wm}\right)_{Q_{\min}} + 0.2\left(\bar{\delta}_{wm}\right)_{0.2Q\max} + 0.4\left(\bar{\delta}_{wm}\right)_{Q_{\max}} . \tag{3}$$

Using numerical data, which were the basis for plotting graphs in Fig. 2, algorithm (3) allowed to build a graph of the change of the generalized WAE from the measured gas volume (Fig. 3).

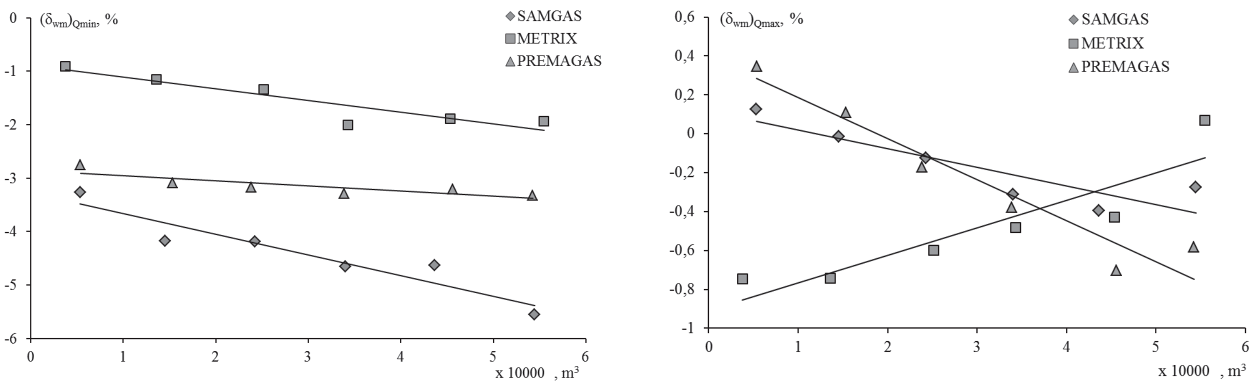

Fig. 2. Illustration of the change of WAE HGM for different measured volumes at operating costs $Q_{\min}$ (*a*), $Q_{\max}$ (*b*)

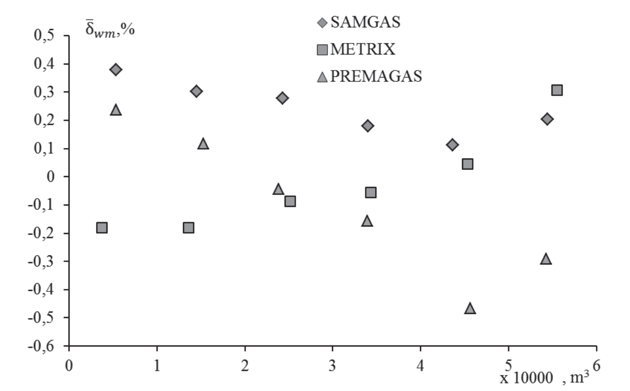

Fig. 3. Illustration of the change of the generalized WAE for HGM of different manufacturers at different measured volumes

The obtained data are ambiguous for different types of household meters. There is a pattern of reduction of the generalized WAE by about 0.07% per 10 thousand m^3 of measured volume for SAMGAS meters and about 0.14% for the PREMAGAS model when measuring their total volume to 45 thousand m^3. At the same time, METRIX meters have the opposite pattern and the negative error is reduced to almost zero and the positive WAE is increased when measuring the volume up to 45 thousand m^3. An unexpected decrease in the negative error and an increase in the positive error of the HGM when accounting for natural gas in the range of over 45 thousand m^3. The authors do not yet have a specific explanation for this. However, it can be assumed that this is due to the operation of the meters after repair, these data reflect the results of verification after the second or subsequent inter-calibration interval. This issue requires further study for another sample of meters, including other models and taking into account the duration of their operation.

Conclusion

Regularities of change of WAE of HGM are established, which give the chance to quantify change of an error from the measured volume of gas at functioning at three standardized for verification expenses, and also to calculate change of the generalized WAE of meter. It was found that the change in the generalized WAE is smaller compared to the change in the WAE of meters when measuring the volume at minimum operating costs. The given results of researches can be the basis for development of methodical material on calculations of losses of natural gas at its account by household meter. Requires further experimental confirmation of the study of the regularity of the change of the generalized WAE when measuring the volume of more than 45 thousand m^3 for different models of HGM. The obtained results open opportunities for quantitative assessment of the change of the generalized WAE of household meters during their operation, which may indirectly characterize the losses of gas supply organizations.

Кваліметричне оцінювання метрологічних характеристик побутових лічильників газу при періодичній повірці

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Анотація

Розглянуто актуальність статистичного оцінювання експлуатаційної похибки побутових лічильників газу (ПЛГ) за результатами повірки після восьмирічного міжповірочного періоду експлуатації. Сформульовано інформативні параметри для здійснення такої оцінки, якими є значення виміряного об'єму впродовж міжповірочного періоду експлуатації й експериментального визначення похибки лічильника при роботі на трьох нормованих витратах: мінімальній, максимальній і 20% від максимальної.

Вибрано шість діапазонів зміни похибки ПЛГ при роботі на мінімальній витраті, які перекривають діапазон похибок від плюс 3% до мінус 30%, для формування статистичних вибірок лічильників. Побудовані гістограми розподілу експлуатаційної похибки ПЛГ різних виробників типорозміру G4 моделей SAMGAS, METRIX, PREMAGAS.

За запропонованим алгоритмом кількісно оцінено зміну зваженої середньої похибки ПЛГ від вимірюваного об'єму для трьох нормованих робочих витрат лічильників з урахуванням кількості ПЛГ і їх діапазонів похибок. Запропоновано застосування поняття узагальненої зваженої середньої похибки ПЛГ, яка відображає експлуатаційні метрологічні властивості ПЛГ при їх роботі у всьому діапазоні витрат при вимірюванні об'ємів газу до 60 тис. куб. м. Ця похибка може бути об'єктивним критерієм для оцінки втрат газопостачальних організацій при обліку природного газу. Виконано кількісний порівняльний аналіз проведених результатів дослідження для ПЛГ вказаного типорозміру і моделей. Встановлено закономірність зменшення узагальненої похибки близько 0,07% на 10 тис. куб. м виміряного об'єму для лічильників SAMGAS і близько 0,14% – PREMAGAS при вимірюванні ними об'єму до 45 тис. куб. м.

Ключові слова: побутовий лічильник газу; похибка; витрата; метрологічні дослідження; статистичні оцінювання; зважена середня похибка.

Квалиметрическое оценивание метрологических характеристик бытовых счетчиков газа при периодической поверке

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Аннотация

Сформулированы информативные параметры для статистической оценки эксплуатационной погрешности бытовых счетчиков газа моделей SAMGAS, METRIX, PREMAGAS. Это значения измеряемого объема в течение межповерочного периода эксплуатации и экспериментально определенная погрешность счетчика при работе на трех нормированных расходах: минимальном, максимальном и 20% от максимального.

Выбрано шесть диапазонов изменения погрешности ПЛГ на минимальном расходе, для формирования статистических выборок счетчиков. По предложенному алгоритму количественно оценено изменение взвешенной средней погрешности ПЛГ для трех нормированных затрат от измеряемого объема с учетом количества ПЛГ и их диапазонов ошибок. Предложено применение понятия обобщенной взвешенной средней погрешности ПЛГ, которая отражает эксплуатационную ошибку ПЛГ при их работе во всем диапазоне расходов при измерении объемов газа до 60 тыс. куб. м. Установлена закономерность уменьшения обобщенной взвешенной средней погрешности около 0,07% на 10 тыс. куб. м измеренного объема для счетчиков SAMGAS и около 0,14% – PREMAGAS при измерении ими объема до 45 тыс. куб. м.

Ключевые слова: бытовой счетчик газа; погрешность; расход; метрологические исследования; статистические оценки; взвешенная средняя ошибка.

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