Application of the coefficient of influence in the calculation of the relative error of gas flow meters

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Abstract: This article assesses the relative error in the operating conditions of gas flow meters and concludes on the applicability of the method of finding the relative error in the operating conditions of the gas flow meter using the coefficient of influence.

Introduction

The oil and gas industry has a great influence on development of the national economy in our country. Oil and gas take the dominating position in power and also in comparison with other natural substances are the most effective and power-intensive [5-8].

In many productions for chemical industry high-quality raw materials – oil gas are used. At such enterprises metering of oil gas which is a valuable natural component belongs to priority tasks of the enterprise. To know exact value of a consumption of oil gas at the enterprises use flowmeters which thanks to the metrological characteristics show concrete values of a consumption of gas in operational conditions.

Thus, the value of an expense shown by the counter is important area for a research as the value of an expense depends on several influencing factors at once (temperature of the surrounding and measured environment, pressure in the pipeline, component composition of gas, etc.)

Presently there is a sharp increase in demand for energy resources and their cost for this reason everyone wants to know about the expense of resources for economy of money [9-11].

There is a set of the devices measuring a flow and amount of substance which differ from each other in the principle of action and a method of measurement. Choosing an expense measuring instrument, experts consider properties of substance, parameters and accuracy of measurement. From this it follows that the accuracy of measurement of resources accepts paramount value [13,15].

Gas therefore gas consumption counters are considered only is mentioned in this work as the measured environment. There are different types of counters of a consumption of gas: vortex, electromagnetic, ultrasonic, etc. All counters of a consumption of gas are intended for achievement of the following purposes:
– Receiving the bases for calculations between the supplier, the gas transmission organization, the gas-distributing organization and the buyer (consumer) of gas, according to contracts of delivery and rendering gas transportation services;
– Analysis of management of the modes of delivery and transportation of gas and also optimization of these processes;
– Providing the balanced system of supply of gas at distribution and transportation of gas;
– Control of rational and effective use of gas.

Now there is a fight for a leading place in the market among the enterprises which are engaged in production of counters for commercial gas metering. Improvement of quality of products is an integral
part of any enterprise which is engaged in production of this or that product. In order that not only to keep in the market, but also to bypass competitors, the enterprises continuously seek for improvement of qualitative characteristics of the products. It is possible to carry the device accuracy as such device implies high quality to qualitative characteristics [12,14,16].

Main part

All enterprises seek for improvement of precision characteristics of the products. For obtaining extreme value of a relative error in technical documentation on counters most the enterprises normalize extreme values of additional errors from change of the influencing factors (for example, temperatures and pressure of the measured environment). That is, the value of an error which we receive in operational conditions should not exceed the extreme value of an error specified in technical documentation.

In most cases the counter – is a complex of measuring instruments which consists of the flow sensor of gas, the sensor of temperature, the sensor of pressure and the calculator. From this it follows that the error of the counter is caused by errors of its components, namely the flow sensor, pressure, temperature and the calculator. Therefore, under operating conditions dynamics of errors of the measuring instruments which are a part of the counter can have significant effect on a relative error of the counter.

With change of conditions under which there is a measurement of a consumption of gas also values of the making errors change, therefore, also the value of a relative error of the counter in general changes. That is, there are additional errors from change of service conditions of a product (in this work: temperatures and pressure of the measured environment).

According to technical documentation on gas consumption counters the consumer knows extreme value of a relative error of the counter of a consumption of gas, but under operating conditions the valid value of an error can differ from the extreme value specified in technical documentation.

Therefore for assessment of a relative error it is under operating conditions expedient to estimate and use so-called functions of influence. Influence function – is dependence of change of metrological characteristics of a measuring instrument on change of the influencing size. According to GOST 8.009 function of influence it is possible to present in the form numbers, formulas, tables or graphics. Also in GOST 8.009 it is mentioned that influence function which passes through the beginning of coordinates can be presented in the influence coefficient form in a numerical look. The first official coefficient of influence was offered by Lionel Penrose in 1946 though the similar idea expressed in 1787 Martin Luther [1-4].

In this article as functions of influence influence coefficients in assumption of linearity of influence of the influencing factors are used. The coefficient of influence shows how the size received at the exit with change of entrance sizes changes. In this case the influencing sizes will be temperature and pressure of the measured environment. This method of calculation is that under operating conditions of the counter enter influence coefficient into a formula of calculation of a relative error (value on curve function of influence).

Influence coefficients from temperature change and pressure find on formulas:

\[
\zeta_T = -\frac{V_{T1} \cdot V_{T2}}{\Delta T} \frac{T}{V_{T2}}
\]

where \(V_{T1}\) = volume under standard conditions at a temperature increased by the size of an absolute error of measurement of temperature \(\Delta T\); \(V_{T2}\) = volume under standard conditions at an average during measurements value of temperature of the measured gas \(T\); \(T\) = temperature of the measured gas; \(\Delta T\) = absolute error of measurement of temperature.

\[
\zeta_P = \frac{V_{P1} \cdot V_{P2}}{\Delta P} \frac{P}{V_{P2}}
\]
where \( V_{PI} \) = volume under standard conditions with a pressure increased by the size of an absolute error of measurement of pressure \( \Delta P \); \( V_{PI} = \) volume under standard conditions at an average during measurements value of pressure of the measured gas; \( P = \) pressure of the measured gas; \( \Delta P = \) absolute error of measurement of pressure.

\( V_{T1} \) and \( V_{T1} \) values are values of the specified volume \( (V) \) and are by a calculation method on a formula:

\[
V' = 2.89 \frac{P_{OC}}{T_{OC}} K_C
\]  

where \( P_{OC} = \) absolute pressure under operating conditions \((\text{kPa})\); \( T_{OC} = \) temperature of the measured environment under operating conditions; \( K_C = \) compressibility coefficient.

In turn the coefficient of compressibility expresses a deviation of properties of real gas from properties of ideal and find it in that case when the received expense needs to be given to standard conditions. The technique of finding of coefficient of compressibility for oil gas is stated in GSSD MR-113. This technique was used for calculations. Besides oil gas, there is a natural gas, the moderate compressed gas mixes, nitrogen and others. For each measured environment there are coefficients of compressibility, according to the techniques stated in GOST 30319.2, GSSD MR 118, GSSD MR 228. For the purpose of saving of time and an exception of mistakes when calculating coefficient of compressibility (an exception of a human factor) at one of the Tyumen enterprises of JSC Dymet the «Physics» program in which above-mentioned techniques for calculation of parameters of the measured gases are realized is developed.

As temperature change of the measured environment and pressure have an impact on an error, influence coefficients from temperature change were calculated (\( \zeta_t \)) with different pressure and from change of pressure (\( \zeta_P \)). at different temperatures. As the measured environment oil gas which exists under conditions from \(-10 \, ^\circ\text{C}\) up to 150 \, ^\circ\text{C} and from 100 \, \text{kPa} to 10000 \, \text{kPa} was chosen. Received value of coefficients are presented in tables 1 and 2.

**Table 1.** Dependence of coefficient of influence (\( \zeta_t \)) from temperature with different pressure \((P)\).

| \( P \), \text{kPa} | 100 | 200 | 300 | 400 | 500 | 1000 | 2000 | 3000 | 4000 | 5000 | 7500 | 10000 |
|-------------------|-----|-----|-----|-----|-----|------|------|------|------|------|------|-------|
| -10               | -1.010 | -1.023 | -1.035 | -1.048 | -1.062 | -1.133 | -1.309 | -1.550 | -1.916 | -2.564 |       |       |
| 0                 | -1.009 | -1.021 | -1.032 | -1.043 | -1.055 | -1.119 | -1.270 | -1.468 | -1.745 | -2.167 |       |       |
| 10                | -1.008 | -1.018 | -1.028 | -1.039 | -1.049 | -1.105 | -1.234 | -1.396 | -1.607 | -1.897 | -3.828 |       |
| 20                | -1.008 | -1.016 | -1.026 | -1.035 | -1.045 | -1.096 | -1.211 | -1.354 | -1.530 | -1.762 | -2.937 |       |
| 40                | -1.006 | -1.013 | -1.022 | -1.029 | -1.037 | -1.079 | -1.170 | -1.276 | -1.401 | -1.553 | -2.119 | -3.476 |
| 60                | -1.004 | -1.012 | -1.018 | -1.024 | -1.031 | -1.065 | -1.139 | -1.222 | -1.317 | -1.423 | -1.773 | -2.342 |
| 80                | -1.004 | -1.009 | -1.015 | -1.021 | -1.026 | -1.055 | -1.116 | -1.182 | -1.255 | -1.336 | -1.577 | -1.909 |
| 100               | -1.003 | -1.008 | -1.012 | -1.017 | -1.022 | -1.047 | -1.097 | -1.152 | -1.210 | -1.272 | -1.452 | -1.673 |
| 120               | -1.003 | -1.007 | -1.011 | -1.015 | -1.019 | -1.040 | -1.083 | -1.129 | -1.176 | -1.226 | -1.363 | -1.525 |
| 140               | -1.003 | -1.006 | -1.010 | -1.013 | -1.016 | -1.034 | -1.070 | -1.109 | -1.148 | -1.189 | -1.300 | -1.422 |
| 150               | -1.002 | -1.006 | -1.009 | -1.011 | -1.015 | -1.032 | -1.066 | -1.100 | -1.137 | -1.174 | -1.274 | -1.382 |

**Table 2.** Dependence of coefficient of influence (\( \zeta_P \)) from pressure at different temperatures.

| \( P \), \text{kPa} | 100 | 200 | 300 | 400 | 500 | 1000 | 2000 | 3000 | 4000 | 5000 | 7500 | 10000 |
|-------------------|-----|-----|-----|-----|-----|------|------|------|------|------|------|-------|
| -10               | 1.008 | 1.015 | 1.023 | 1.031 | 1.040 | 1.085 | 1.195 | 1.343 | 1.576 | 1.982 |       |       |
| 0                 | 1.007 | 1.013 | 1.021 | 1.028 | 1.035 | 1.074 | 1.168 | 1.290 | 1.454 | 1.718 |       |       |
| 10                | 1.003 | 1.006 | 1.008 | 1.011 | 1.016 | 1.031 | 1.064 | 1.132 | 1.184 | 1.278 | 1.874 |       |
| 20                | 1.005 | 1.010 | 1.016 | 1.022 | 1.027 | 1.055 | 1.127 | 1.203 | 1.308 | 1.436 | 2.141 |       |
| 40                | 1.004 | 1.008 | 1.013 | 1.017 | 1.021 | 1.043 | 1.096 | 1.154 | 1.228 | 1.305 | 1.610 | 2.374 |
| 60                | 1.003 | 1.006 | 1.010 | 1.014 | 1.017 | 1.035 | 1.074 | 1.114 | 1.163 | 1.208 | 1.384 | 1.677 |
On the received values of coefficients of influence schedules on which influence of temperature and pressure upon an error is clearly visible for descriptive reasons were constructed.

**Figure 1.** The schedule of dependence of coefficient of influence ($\zeta_t$) from temperature with different pressure (P)

**Figure 2.** The schedule of dependence of coefficient of influence ($\zeta_p$) from pressure at different temperatures (t)
To make assessment of this method, calculations of a relative error of the counter taking into account extreme values of the additional errors specified in its technical documentation and also calculations taking into account influence coefficients under operating conditions were carried out. As an example the counter of a consumption of «DYMETIC-1261-G» gas is used. These counters are made by the Tyumen firm JSC Daymet which is engaged in production of various measuring instruments of an expense since 1993. This counter consists of the flow sensor of gas, the sensor of temperature, the sensor of pressure and the microcomputer. In this case at the exit we will have a relative error of the counter, and an entrance will be the making errors.

Calculations of a relative error of the counter were carried out on two formulas:

\[
\delta_{\text{V1}}^{\text{SC}} = \pm \sqrt{\delta_V^2 + \delta_{\text{add}}^2 + \delta_P^2 + \delta_t^2 + \delta_{\text{calc}}^2}
\]

(4)

where \(\delta_V\) = limits of the allowed relative error of the counter caused by an error; \(\delta_{\text{add}}\) = limits of the allowed additional error of the counter from temperature change; \(\delta_P\) = limits of the allowed additional error of the counter from change of pressure of the measured environment; \(\delta_t\) = limits of the allowed relative error of the counter caused by an error of measurement of temperature; \(\delta_P\) = limits of the allowed relative error of the counter caused by an error of measurement of pressure; \(\delta_{\text{calc}}\) = limits of the allowed relative error of the counter caused by errors of calculation of the volume specified to standard conditions.

\[
\delta_{\text{V1}}^{\text{SC}} = \pm \sqrt{\delta_V^2 + \left(\delta_V + \delta_t\right)^2 + \left(\delta_P + \delta_P\right)^2 + \delta_{\text{calc}}^2}
\]

(5)

where \(\zeta_t\) = value of coefficient of influence of an error of measurement of temperature of the taken environment; \(\zeta_P\) = value of coefficient of influence of an error of measurement of pressure of the measured environment.

**Conclusion**

As a result of the carried-out calculations the following values of errors, a part of which is presented in table 1, were received.

**Table 3. Results of calculation of an error**

| Conditions (temperature, pressure) | \(\delta_{\text{V1}}^{\text{SC}}, \%\) | \(\delta_{\text{V1}}^{\text{SC}}, \%\) |
|-----------------------------------|--------------------------------|--------------------------------|
| T = + 10°C                       | 1.61                           | 1.60                           |
| P = 200 kPa                      |                                |                                |
| T = + 40°C                       | 1.71                           | 1.68                           |
| P = 500 kPa                      |                                |                                |
| T = + 60°C                       | 2.89                           | 2.82                           |
| P = 500 kPa                      |                                |                                |

From the obtained design data it is possible to draw a conclusion that this method of assessment of an error can be applicable for finding of the valid value of the main relative error under operating conditions of the gas consumption counter as the received value of an error does not exceed extreme permissible value of a relative error.

This method of assessment of a relative error will be under operating conditions very convenient for consumers who want to know real value of the consumed gas for the purpose of economy of financial resources.

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