Improvement of metrological reliability in the measurement of coolant flow and the amount of heat at housing and communal facilities

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Abstract: The authors examine dynamic and metrological characteristics of a vortex-acoustic flowmeter, a classification, a brief description, and the operation principle of widely used flowmeters. They present the results of research and exploitation of vortex-acoustic and electromagnetic flowmeters within the calibration interval (CI), obtained on an automated laboratory research test bench. The authors give some practical advice on choice of devices for flow metering based on the procedure of metrological reliability.

1. Introduction

In accordance with the Federal law, state institutions and objects of housing and communal services must use heat and energy metering devices, which include heat meters and flow meters of hot and cold water supply.

Heat meters (TC) are designed to measure the amount of heat consumed, as well as the flow of the coolant. The amount of heat consumed is calculated for various typical heat supply schemes according to the following algorithms:

For closed heat supply systems

\[ Q = G_1(h_1 - h_2) \]

for the open heat supply systems, analysis of hot water:

\[ Q = G_1(h_1 - h_2) + G_3(h_1 - h_x), \]

where \( G_1,h_1 \) – mass flow rate and enthalpy of coolant in the supply, direct pipeline; \( h_3, h_x \) - enthalpy of coolant in the return pipeline and feed, determined by the temperature \( T_3,T_X \); \( G_3 \) - mass flow of water for household needs [1,2].

According to the algorithm of calculation of thermal energy in the composition of any heat meter should include two temperature sensors, one or more sensors of coolant flow and hot water and microprocessor calculator (Fig. 1).
Figure 1. The structure of the vehicle for the closed heat supply system:
V1, T1 – flowmeter and thermometer on the supply (direct) pipeline of the heating network;
T2 – thermometer on the return pipeline; MK – microprocessor heat exchanger [11].

When measuring thermal energy it is necessary to ensure the uniformity of measurements. Accuracy indicators in the calibration interval (MPI) should not exceed the established limits. These boundaries for heat meters are the main permissible errors of measuring instruments that are part of the heat meter. Used sets of temperature sensors – platinum resistance thermometers tolerance class B – sufficiently accurate SI with the basic permissible error and expanded uncertainty of not more than ±0.25% of the VPI [3,8]. While the basic permissible error of industrial flowmeters is in the range of ±0.75% ... ±1% of full scale (tab.1) [4,10]. Thus, the error of flow meters is the influencing factor on the error of the heat meter. Investigation of the metrological reliability of the flow meters with the aim of improving the accuracy of measurement is important.

A wide variety of flowmeters of different operating principles is known [5,6]. Currently, two types of heat meters are certified: electromagnetic and eddy-acoustic flow meters. Historically, the main flow meters included in the heat meter were electromagnetic or induction flow meters under the original name. The principle of operation of electromagnetic flowmeters is based on the law of electromagnetic induction - Faraday’s law: the dependence of the EMF of induction arising in the flow of conductive liquid passing through the electromagnetic field on the volume flow.

The equation NSH meter [11]:

\[ E_u = \frac{4B_{\text{max}} \sin \omega t}{\pi D} G_0, \]  

(3)

where \[E\] is the EMF of induction, B is the characteristic of the magnetic field, magnetic induction, \(\omega = 2\pi f\) is the circular frequency, here \(\pi = 3.14\), D is the distance between the electrodes, Go is the volume flow rate.

From equation (3) it follows that the accuracy of the flow meter will depend on the constancy of parameter D. As shown by the experience of operation, this parameter changes due to the increase in the roughness of the lining and its silting, as well as the formation of deposits of iron oxides (rust of heat pipes) under the action of a magnetic field. These phenomena cause occurrence and increase of multiplicative error and decrease of metrological reliability of both flow meter and heat meter as a whole [5,6].

2. Materials and Methods

Studies of the metrological characteristics of two types of flow meters – electromagnetic and vortex sonic - was conducted on an experimental automated installation of the research laboratory of the Department of APP the Irkutsk national research technical University (Fig.2).
Water from storage tank 1 (Fig. 2) it is fed by a pump to the upper vessel of a constant level 3, from where, under a constant pressure, passing through the test flowmeter Metran – 300 PR (5) and the ball valve (4), enters the measuring vessel 6. The filling time of the measuring vessel from the lower to the upper level is measured by a timer. The calculated value of the volume flow is calculated by the formula:

\[ F_0 = VM / \tau_{cp} \text{, where } \tau_{cp} = \sum ti / n \]  

(4)

Data visualization was carried out with the help of SIMATIC WinCC data collection and visualization system.

3. Experimental Section

Multiple measurements of water flow by two different types of flow meters: electromagnetic and eddy-acoustic. The actual flow rate was determined using a spillway system, the relative error of the flow meter and the coefficient of variation were automatically calculated. The experiment was controlled by Simatic S7-300 controller. The results of the measurement of the filling time of the measuring vessel and the eddy-acoustic flow meter readings for the five flow values are presented in Table 2 and Figure 3.

| Degree valve opening, % | The time required for filling the measuring pouring set, sec | Indications eddyacoustic flowmeter, m³/h | Relative Error, % |
|--------------------------|---------------------------------------------------------------|----------------------------------------|-------------------|
| 40                       | 29,9                                                          | 1,55                                   | 0,103             |
| 50                       | 23,2                                                          | 1,64                                   | 0,140             |
| 60                       | 18,8                                                          | 1,83                                   | 0,192             |
| 70                       | 14,5                                                          | 2,11                                   | 0,286             |
| 80                       | 12,9                                                          | 2,54                                   | 0,388             |
Figure 3. Change in the relative error of VAR along the length of the scale.

The results of measuring the volume flow of the electromagnetic flow meter are presented in a graph (Fig. 4).

![Graph showing change in relative error of VAR along the scale.]

4. Results and Discussion
As shown by the operating experience, this parameter $D$ changes due to the increase in the roughness of the lining and its silting, as well as the formation of deposits of iron oxides (rust of heat pipes) under the action of a magnetic field. As shown by the operating experience, this parameter changes due to the increase in the roughness of the lining and its silting, as well as the formation of deposits of iron oxides (rust of heat pipes) under the action of a magnetic field.

Table 2. Comparative analysis of electromagnetic flowmeters of domestic and foreign manufacturers.

| Characteristics       | VZLJOT | METRAN –370 | OPTIFLUX 2050 | OPTIFLUX5100 |
|-----------------------|--------|-------------|---------------|--------------|
| Relative error, %     | $\pm 0,5\ldots\pm 0,85$ | $\pm 0,5\ldots\pm 0,6$ | $\pm 0,5\ldots\pm 0,85$ | $\pm 0,65\ldots\pm 0,4$ |
| Electroconductivity, mSm/cm | $\geq 20$ | $\geq 20$ | $\geq 20$ | $\geq 20$ |
| Content solid, %      | Not more10 | Not more10 | Not more10 | Not more10 |
| MPI, year             | 4      | 2           | 2             | 2             |
| Cove                  | Phtoroplast | Phtoroplast P-4 | Phtoroplast PFA. | $Al_2O_3, Ta_2O_3$ |

To avoid reducing the metrological reliability during the operation of heat meters it is recommended to install MPI not more than two years (for heat meters on the basis of the EMR); or you can apply heat on the basis of other types of flowmeters that do not use a magnetic field, for
example, vortex sonic. Confirmation of the results of our research is that some manufacturers have used other lining materials in electromagnetic flowmeters instead of fluoroplast, which significantly increases the cost of the product itself (Table. 2).

5. Summary and Conclusion

Conclusion:

- Basic relative error in the experiment, the vortex sonic flow meter does not exceed the allowable values;
- Work EIR has been much instability;
- From the equation of the nominal static characteristic (3) of the electromagnetic flow meter, it follows that the accuracy of the flow meter will depend on the constancy of the parameter D (the distance between the electrodes), the geometry of the flow section.

As shown by the operating experience, this parameter changes due to the increase in the roughness of the lining and its silting, as well as the formation of deposits of iron oxides (rust of heat pipes) under the action of a magnetic field. These phenomena cause the occurrence and increase of multiplicative error and decrease in metrological reliability of both the flow meter and the heat meter as a whole. To avoid reducing the metrological reliability during the operation of heat meters it is recommended to install MPI not more than two years (for heat meters on the basis of the EMR); or you can apply heat on the basis of other types of flowmeters that do not use a magnetic field, for example, vortex sonic.

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