METROLOGICAL MAINTENANCE OF JUNCTIONS FOR METERING HEAT ENERGY AND HOT WATER

Yu. V. Tarbeev, P. V. Novitskii, V. I. Mishustin, and A. G. Lupei

A new approach to estimating the error in measuring heat energy and the flow rate of hot water at metering junctions is proposed. The results of the analysis enable one to determine the sources of systematic errors, to formulate the requirements imposed on the metrological characteristics of the units which form part of the heat meters, and on the conditions and aims of the check, and also enable the idea of "metrological maintenance" to be introduced.

The need to develop new standard documents which regulate the approach to error estimates is pointed out.

Heat energy and hot water metering junctions are designed to carry out financial calculations and to ensure that the technical needs of the heat-supply organisation are met. This includes the need for monthly (ten-day, daily or shift) information on the balance of the mass flow rates of hot water, the balance of heat energy to each consumer, of each heat pipeline and source of heat as a whole, and also includes the need to determine the payment due for the current month for heat and hot water supplied and consumed.

For the majority of heat producers the metering junctions are provided with automatic recording instruments, but for many consumers the metering junctions are equipped with heat meters. Hence, all the recommendations and limitations mentioned below relate to metering junctions in which both automatic recording instruments and heat meters are used.

The error in determining the heat energy and hot water flow rate using metering junctions (heat meters) is indicated in the standard documents by appropriate classes of 2, 4 or 5, i.e. it depends on the thermal mode of operation of the heat supply system and lies in the range from 2% to 4%, from 4% to 6% or 5% to 8% respectively. However, the actual disagreement between the readings of the metering junctions of the suppliers and consumers often reaches 20–40%. It is easy to show this at the point of use. All one has to do is interchange the thermometers or flow rate meters in the feed and return pipelines and take readings of the thermal power. It will be found that in one of their positions it shows, for example, 40% of the scale and in the other 60% of the scale. This is due to a number of factors, which we will consider below.

The first reason is the lack of standard documentation on heat-meter readings regarding the need to estimate the systematic errors that occur when determining small differences between large subtracted quantities.

The relative systematic error which arises when determining $AX$ when making the subtraction $X_1 - X_2$ (no matter how this subtraction is carried out – by a human from the recordings in journals and from the diagrams of automatic recorders or by a microprocessor calculator) will always be somewhat greater than the relative errors $\delta(X_1)$ and $\delta(X_2)$ in determining each of the quantities $X_1$ and $X_2$, due to the instrumental errors of the measuring instruments employed.

In the algorithm of the operation of the heat energy and hot water metering junction the subtraction operation is carried out three times: when determining the temperature differences, the flow rates and the thermal energies. The systematic errors that occur then manifest themselves not in the fact that some definite "systematic error" is added to the sum of the instrumental errors of the measuring instruments employed, but in the fact that the relative error in determining the difference is $k$ times greater than the instrumental errors of the instruments employed, where $k = (X_1 + X_2) / (X_1 - X_2)$ is the systematic coefficient, which increases the relative error of the difference obtained manyfold.

A method of ensuring that the metering junctions operate correctly under these conditions was found long ago in practice and consists of using matched pairs of thermo-meters, flow-rate meters and similar heat calculating instruments with the same sign and with almost identical systematic errors. This needs to be included in the standard documentation.
The second reason is a consequence of the first and is that the errors introduced by the fact that the pairs are unmatched can be described by analytic formulas only using the individual characteristics of the errors of each of the elements of the pair (by algebraic subtraction of the errors of the elements, taking their signs into account) and cannot be described if the errors of the elements are only indicated by their limiting values, which are either summed in modulus or squared and thereby lose their signs. This is due to the fact that the error of the difference is the algebraic difference of the errors of the reduced and subtracted errors, and this error with its sign can only be obtained from the individual characteristics of the errors of the two converters of the pair used.

Consequently, metrological testing of a metering junction must be based on the individual characteristics of the error of its individual units.

The third reason is due to the fact that the standards on thermometers and flow meters, used at the junctions where heat energy and hot water are measured, have not foreseen their production as matched pairs. Nevertheless, all the prerequisites required for this have already been introduced in other standards. Thus, in the State Standard GOST 8.009-84 (Appendix 3, Section 13) the idea of "the individual conversion function of a measuring transducer, obtained experimentally for a specific specimen" was introduced, and the State Standard GOST R 50353-92 in Sections 1.3 and 2.9 provides that, for a specific type of resistance thermometer, individual static characteristics can be presented. This approach is used in the State Standard GOST 26.203-81 "Measuring-Computing Systems," where Section 4.8 specifies that measuring-computing systems should be tested metrologically on the basis of an experimental determination of the individual metrological characteristics of their measuring channels.

On the basis of these standards it should become standard practice to include in the operation of checking thermometers, flow meters and the calculators of the units for measuring heat energy and hot water a determination of the individual characteristics of their error as a function of the values of the measured quantities and the selection of matched pairs of thermometers, flow meters, and similar heat meters.

In view of this, the requirements imposed on thermometers of classes A, B and C according to the State Standard GOST R 50353-92 for their use in commercial metering junctions and heat meters must be supplemented by the requirement that only matched pairs of thermometers with known individual characteristics of the systematic errors should be used at metering junctions (including factory matched pairs, for example, the KTSPR, KTPTR or other units), which make a contribution to the relative error in determining heat energy, for example, of not more than 1% for a temperature difference $T_1 - T_2 \geq 10 \degree C$ and 2% for $T_1 - T_2 = 5 \degree C$.

The fourth reason is due to the need for annual metrological servicing of flow meters and analog heat meters for producing and maintaining matched pairs and consists of the following.

The resistance thermometers used in metering junctions do not have regulating systems. Hence, the design of matched pairs in this case consists solely of choosing pairs of existing thermometers. The majority of modern flow meters and analog registers have units for regulating the zero and the sensitivity of their calibrated characteristics. Hence, the production of matched pairs of these units consists not so much of choosing them but of careful appropriate regulation of the zero and sensitivity of their characteristics.

If the regulation is not carried out correctly the error of the flow meter will exceed its minimum possible fundamental value by a large factor (5–10 fold) due to the nonlinearity of the characteristic. Hence, daily regulation of the characteristics of flow meters is an important part of their regular metrological maintenance. However, the procedures for regulating the characteristics of flow meters by alternately regulating the zero and the sensitivity, as recommended in the factory instructions, i.e., the "trial and error" method, is very time consuming. As a result, a check of flow meters, though only those obtained from factory repair, shows that the above requirement is often not fulfilled even in the case of factory regulation.

A rational solution of this problem is to use a special computer program for checking which, by analyzing the relation between the flow-meter errors at checked points indicates to the operator the values of the output signal which he should set for $G_{\text{min}}$ and $G_{\text{max}}$ to obtain the optimum flow-meter characteristics from the very first.

Taking into account the methods of overcoming the third and fourth factors responsible for large measurement errors in measuring heat energy, we can formulate the following general rules.

At the junction points in the supply and reverse pipelines one should only use matched pairs of thermometers, flow meters and analog calculators, chosen in accordance with their individual characteristics.