Development of metrological methods for determining the balance of water and heat of generating companies

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Abstract. The paper considers the causes of unbalance at the heat source during the normative consumption of resources, and also presents the results of the analysis of the metrological method of reducing the balance with statistical data and calculating the economic effect. Additionally, there are three options for solving the problem of unbalance, indicating the estimated economic effect for the station. The paper presents studies on the assessment of the imbalance in the supply and consumption of heat of an energy generating enterprise with a mixed consumption structure (instrument accounting, regulatory accounting). The possible solutions proposed in this work are based on the existing approach to estimating the uncertainty of instrumentation and are tested on arrays of statistical data from thermal power plants. For the proposed solutions to the problem of unbalance, an assessment of economic efficiency is made.

1. Introduction
Regardless of the billing period, at any source of heat, the problem of inconsistency of the results of accounting for consumed cold water and make-up water supplied to heating networks arises. This phenomenon is called the "occurrence of unbalance." The more powerful the heating main, the higher the level of divergence in the results of accounting for cold and make-up water. Unfortunately, in the current regulatory documentation, methods for solving this problem are not specified.

At the 6th All-Russian scientific and technical conference “Metrological support of energy resources accounting”, the ideas about introducing metrological methods of reducing the balance of water and heat in the legal field were presented[9]. Unfortunately, over the past 14 years, methodological foundations and regulatory documentation have not been developed that would regulate the sequence of actions when taking measurements and distributing unbalances in energy resources. If we assume that at the station all the measurements were made correctly, but the imbalance is present, then with a high probability the cause of this problem is the systematic errors of the measuring instruments.

The study of the causes of the inconsistency of the accounting results will reveal the stage at which the error occurs and analyze possible solutions. Taking into account the fact that the majority of household consumers are calculated according to the consumption standard, the occurrence of unbalance is inevitable, since the average volume of water consumption by standard consumers is less than paid, respectively, the station receives a positive unbalance from them. Depending on the size of the settlement, the consumption standard may vary. Often, regional water tariffs exceed tariffs in Moscow and St. Petersburg, which is not a positive factor, since the standard of living in the regions and average wages are lower than those in the capital.
The factors that cause unbalance when accounting for the released and consumed water at the CHPP include the following:

1. Systematic errors of the used measuring instruments (provided that at the CHPP all necessary measurements are organized and performed correctly). Justified, in this case, will be the reduction of water balances taking into account the normalized metrological characteristics of all measuring instruments, the readings of which to one degree or another can affect the amount of unbalance. In this case, the correction of the obtained results in order to eliminate the unbalance should be carried out taking into account the following rules: only those measurement results that can cause the unbalance should be adjusted; the sign of the amendment to be introduced should be such that its application helps to reduce the discrepancies; the relative magnitude of the corrections should be directly proportional to the limits of permissible relative measurement errors of the corresponding quantities; the proportionality coefficient should be the same for all metering devices and determined by the ratio of the actual unbalance to its maximum permissible value.

2. Consumers using water according to the standard. Despite the need to install meters in each apartment, a large part of the population pays for water in accordance with the standards assigned to a particular region (city). Often, the consumer does not consume the amount of water that was allocated to him according to the documentation, which in turn provokes a positive unbalance, since the unspent water in fact is returned back to the station, at the time when it is officially registered as waste by consumer. Hence the use of "excess water", returning to the station in the status of spent.

2. Materials and methods
The main objective of the study is to eliminate imbalances in the heat source in the presence of contracts with household subscribers who consume resources according to standards.

The most common are two situations. The most common, in which the station does not conclude agreements on the provision of heating and water supply services directly with the subscriber, but uses an intermediary in this chain represented by the Heating Network organization, which in turn is already providing services in this area (Figure 1)

![Figure 1. Intermediate Services Scheme](image)

The second option is the conditions under which there is no intermediate link, as a result of which the CHPP directly concludes a contract with the consumer [14].

Depending on the accepted initial situations, options for solving the problem of unbalance will be different. One of the solutions to this problem is the transition from standard consumption to the use of instrumentation for all consumers. In this case, it is possible to reduce the unbalance, based on the permissible relative errors of the measuring instruments.

The second solution to the problem of unbalance is to increase the uncertainty component in the presence of regulatory consumers by 50%, and the excess water is supposed to be used, as indicated below, in the third solution [7].

The third solution option is to redistribute the resulting water into waste tanks [17] with further processing and use for the needs of the CHPP.

Consider the ways to solve the problem of inconsistency in the results of accounting for released


and consumed water in highways. In particular, the approach to reducing unbalance according to the first scheme, that is, in the case when the CHPP does not conclude a direct contract for the provision of services with a substitute, but uses an intermediate link - the company "Teplosety".

In this case, the company "Teplosety" buys water from the CHPP and provides it to consumers. Regardless of whether they use water according to the standard or keep records of consumption by meters, consumers make payments for water to the Heat Network company. Surplus water arrives at the station marked “not used/not paid”. A station cannot use such a resource for its own needs; excess water is not a source of positive unbalance in this case. Thus, the only possible way to reduce the imbalance is to take into account the values of the permissible relative errors of the MI. It will be necessary to evaluate the errors of all MI and the unbalance coefficient for further amendments to the accounting.

In a situation where the CHPP concludes an agreement on the provision of services directly with consumers, a positive unbalance at the station is provoked [19].

In such a situation, one of the solutions to the problem will be the rejection of normative consumption with a complete transition to instrument metering (using meters). This method will be able to facilitate the process of reducing imbalance by metrological methods using the values of the maximum permissible relative errors of measuring instruments (MI). Given that household consumers are reluctant to independently install water meters, this task can be assigned to the parent company, which includes the CHPP. An assessment was made of the number of normative consumers of one of the stations in St. Petersburg operating in two districts of the city. The total number of consumers reaches 750 thousand people, of which about 30% are regulatory consumers. The costs of the parent company for the provision of instrument metering for the studied group of consumers will amount to more than 200 million rubles. during one inter-verification interval, or, on average, more than 40 million rubles / year.

When implementing this set of measures, it is possible to simplify the process of reducing the unbalance at the CHPP, but unfortunately the station will not receive an additional economic effect, except for reducing the cost of compensating for the unbalance.

The essence of the second unbalance reduction scheme is to increase uncertainty by 50% when taking into account the water consumed by regulatory consumers. By supplying water, we can not reliably determine the amount of water used by a particular consumer who does not have the means of metering. This means that there is an additional component of the total uncertainty of water accounting. The general formula for calculating the total uncertainty of the mass flow of water can be written as:

\[ u'q = \left(u' c^2 + u' \kappa_r^2 + u' \kappa_c^2 + \left(\frac{2 + \beta^2}{1 - \beta^2}\right) u' D^2 + \left(\frac{2}{1 - \beta^4}\right) u' d^2 + 0.25 \left(u'_{2p}^2 + u'_{3p}^2\right)\right)^{0.5} (1) \]

where, \( u' c^2 \) - relative standard uncertainty of the expiration coefficient; \( u' \kappa_r^2 \) - the uncertainty of the correction factor, taking into account the roughness of the inner surface of the measuring pipeline; \( u' \kappa_c^2 \) - the uncertainty of the correction factor, taking into account the blunting of the input edge of the diaphragm; \( \beta \) - is the relative diameter of the opening of the constricting device [1]; \( u' D^2 \) - the uncertainty of the dimensions of the outer diameter; \( u' d^2 \) - the uncertainty of the dimensions of the inner diameter; \( u'_{2p}^2 \) - uncertainty of the measurement result; \( u'_{3p}^2 \) - the uncertainty of the measurement result of absolute pressure [4].

By adding to this formula the coefficient \( u_{2p} \), which is responsible for the uncertainty of consumption at standard consumption and equal to 50%.[20]

As another alternative solution to the problem of unbalance, redistribution of the received excess water from the subscriber to waste tanks can be made with a view to its further processing and use for the station's needs [19]. With normative consumption, in most cases, the consumer does not use the amount of water that is allocated to him according to regulatory documentation. This in turn provokes a positive unbalance at the station. The solution to this problem will be the transfer of the resulting water to the category of waste for the purpose of its further processing. After the station purifies such water, it can use it for its needs. The average volume of water used at the station for domestic
consumption is about 100 thousand cubic meters. m., which is less unbalance from regulatory consumers. Thus, the returned water is sufficient to meet the needs of the station and it is possible not to buy water from the water utility, which has an additional economic effect.

3. Discussion
In accordance with GOST 8.586.5-2005, the relative expanded uncertainty for the measured value at P = 95 will be calculated by the formula

$$U'q = 2 * u'q$$

(2)

Intermediate variables for formula 1 are determined by the following formulas:

$$u'c = 0.5 * (U'c_0 + U'L + U't + U'ax + U'h)$$

(3)

where, $U'c_0$ - is determined in accordance with table 1.

Table 1. Formulas for determining the uncertainty of the expiration coefficient depending on $\beta$ [2]

|   | Formula |
|---|---------|
| 1 | $U'c_0 = 0.7 - \beta$ at $0.1 \leq \beta < 0.2$ |
| 2 | $U'c_0 = 0.5$ at $0.2 \leq \beta \leq 0.6$ |
| 3 | $U'c_0 = 1.667*\beta - 0.5$ at $0.6 < \beta \leq 0.75$ |

Since the flow meters of variable differential pressure (FVDP) [8] is a high-precision metering device, the remaining parameters do not introduce additional uncertainty into the expiration coefficient. If a different flow meter is installed in the metering unit (electromagnetic [16], ultrasonic, but it is necessary to rely on the metrological characteristics of a particular measuring instrument) [15].

In accordance with GOST 8.586.5-2005, clause 10.3.2 of the value $u'd = 0.02\%$, and $u'D = 0.1\%$, the uncertainty of the measurement result is determined by the formula:

$$u'\Delta p = (\sum_{i=1}^{n} (\delta_l * u'y_i)^2)^{0.5}$$

(4)

where, $n$ - is the number of measuring instruments used to measure the differential pressure; $\delta_l$ - is the sensitivity coefficient of the i-th measuring device; $u'y_i$ - uncertainty introduced by the i-th measuring device.

The next step will be to determine the absolute error of mass measurement.

To determine the magnitude of our amendments, we must calculate the unbalance coefficient by the formula 5.

$$K_{ub} = \frac{K_f}{K_{max}}$$

(5)

where, $K_f$ is the value of the actual unbalance present at the station; $K_{max}$ is the maximum possible unbalance at the station.

Knowing the unbalance coefficient, we make the necessary corrections to the relative errors, multiplying the unbalance coefficient by the permissible relative error of the measuring instrument. After making adjustments, the unbalance value should tend to zero. To achieve a positive result of adjustments, it is necessary to take into account the amendments made, in the heat released on the highways [6].

For the above methods of solving the problem of inconsistency in the results of accounting for discharged water by highways and used water, economic indicators were calculated [13].

The event that has the greatest economic effect should be considered the use of water that was not used by regulatory consumers for the needs of the CHPP plant by transferring the resource to waste, with the aim of cleaning it and further using it. The estimated annual economic effect in prices of 2018
will be about 30.0 million rubles, which is a significant amount in the balance of the studied enterprise.

4. Conclusion
In order to eliminate the imbalance caused by systematic errors of the measuring instruments used (by which the incoming and outgoing water is recorded), the maximum permissible errors of the flow meters are calculated according to the method specified in the current regulatory documentation, namely GOST 8,585.5-2005, and the necessary amendments are made to initial measurement results.

The methods for reducing imbalance described in this work can have their practical application both independently and in combination, which will depend only on the available array of source data. After analyzing all the methods of reducing imbalance, it should be noted that the most economically promising is the one in which the CHPP directly concludes a contract with the subscriber and uses its excess water for its needs, which saves money by stopping the need to buy water for its needs from Vodokanal and the need to compensate for unbalance at their own expense.

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