UDC 628.1

ISSN 2617–1848

DEVELOPMENT OF APPROACHES TO IMPROVE THE EFFICIENCY AND RELIABILITY OF WATER SUPPLY SYSTEMS FOR BOILER HOUSES (FOR SMALL FACILITIES)

N.G. Nasonkina, Dr. Sc.; E.A. Feskova; P.G. Bereza;
V.S. Zaburdaev; O.E. Zhukov
STATE EDUCATIONAL INSTITUTION OF HIGHER PROFESSIONAL EDUCATION “DONBAS NATIONAL ACADEMY OF CIVIL ENGINEERING AND ARCHITECTURE” MES DPR, Makeevka

N.G. Nasonkina

E.A. Feskova

P.G. Bereza

V.S. Zaburdaev

O.E. Zhukov

Annotation: **Most of the small boiler houses in the Donetsk People’s Republic are not separated by separate levels, which leads both to a decrease in the reliability and efficiency of their operation, and to a significant complexity in the implementation of their water supply management. In this article, the authors consider the main ways to improve the efficiency of water supply systems for boiler houses, and also present an analysis of the factors affecting the reliability of water supply systems, their failures, operating conditions and energy consumption. The structure and classification of tasks for the reliability of water supply systems is given. A water supply system with low energy consumption for boiler houses is proposed. Studies show that as a result of targeted system management, it is possible to reduce water losses and use the technological reserve for upgrading systems, taking into account wastewater heat recovery.**

Key words: **boiler room, water treatment, water supply system, osmosis.**

FORMULATION OF THE PROBLEM AND ANALYSIS OF RECENT RESEARCH

The main task of the technical operation of boiler water supply systems is to ensure the reliable operation of all elements and reduce energy consumption during the operation of boilers. A significant number of works are devoted to the issue of water treatment for boiler houses [1-12].

The structure and classification of tasks for the reliability of water supply systems for boiler houses is shown in Figure 1. It should be noted that for water supply systems for boiler houses, the main indicators of reliability are the probability of failure-free operation P and the availability factor KG:

$$P^*(t) = 1 - \frac{n(t)}{N_0}. \qquad (1)$$

where N is the number of elements at the beginning, pcs.;

n(t) - the number of elements that failed during the time t, pcs;

$$K_r = T_c \big/ (T_c + T_B) \qquad (2)$$

where Tc – time between failures;

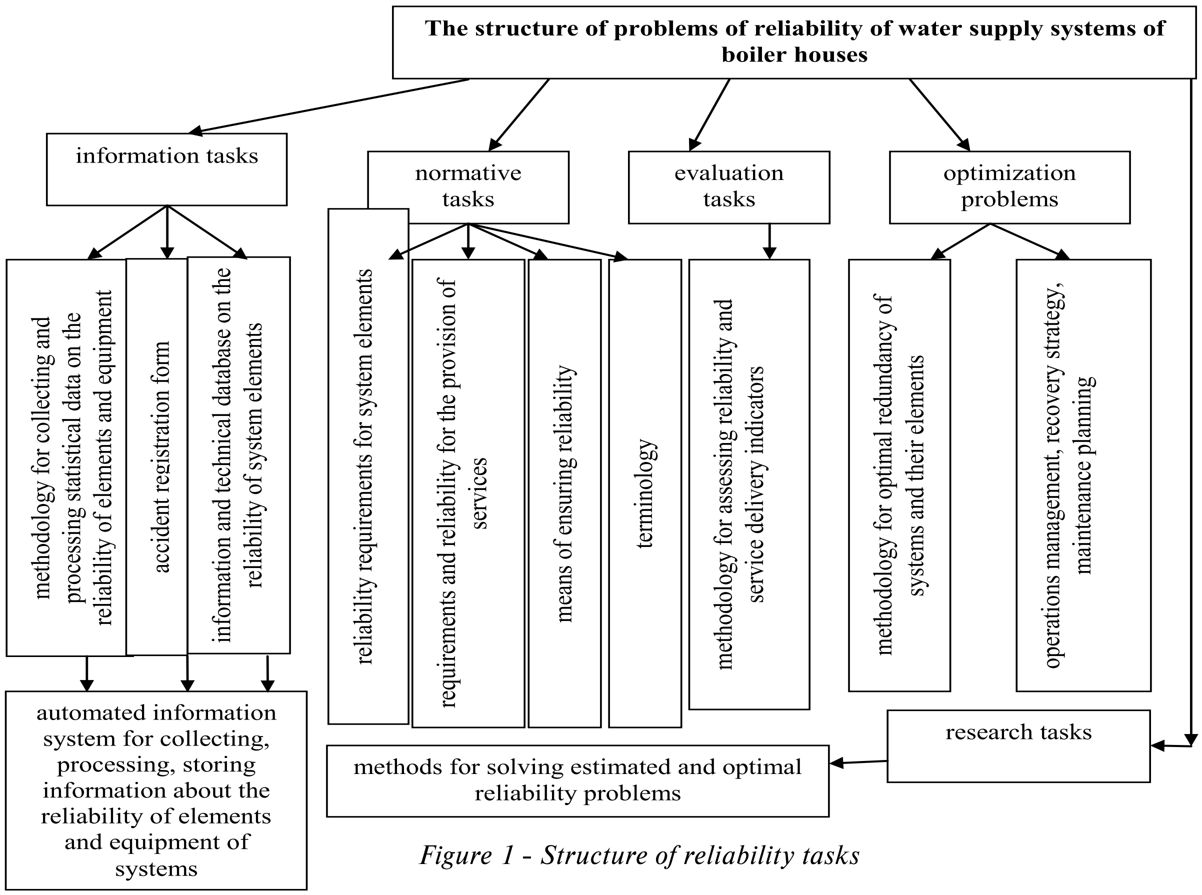


Figure 1 - Structure of reliability tasks

TV - average recovery time.

$$T_c^* = 1/n \sum_{i=1}^{n} t_i \qquad (3)$$

where ti is the time of correct operation of the object between (i-1) -m and i-th failure;

n is the number of failures over time t.

If we set the task of studying the influence of a variety of individual factors on the process of correct operation of the system, then, as can be seen from Table 1, the research program for its solution seems to be rather complicated. It becomes disproportionately more difficult when identifying relationships between variables. Therefore, when conducting research, it seems relevant to identify the nature of the functional relationship between the main variables.

Table 1. Classification of variables affecting the operation of the water supply system of boiler houses

Controlled parameters [X(t)]	Control actions [Y(t)]	Disturbances [Z(t)]
Q(t) - performance. Pout (t) – pressure; Pdt(t) - pressure at the dictating point; N(t) - power consumption, □(t) – plant efficiency, C (t) - the composition of the supplied water	Q(t) - performance. Pout(t) - pressure Pdt(t) - pressure at the dictating point Zdv(t) is the state of the elements, C (t) - the composition of the supplied water	Qc(t) - daily unevenness of water consumption QA(t) – leakage, Pv(t) - pressure Rk(t) - equipment wear 3(t) - reinforcement condition □(t) - overgrowth of pipes and boilers C (t) - composition of water

As can be seen from Table 1, the main parameters for regulating the operation of the water supply system of boiler houses are productivity, electricity consumption, and the quality of the supplied water.

PURPOSE OF THE WORK: to study the reliability of water supply systems for boiler houses and develop approaches to optimizing their operating conditions, taking into account the reduction in electricity costs.

MAIN MATERIAL

Most of the small boiler houses in the Republic are not isolated by individual levels, which leads both to a decrease in the reliability and efficiency of their operation, and to a significant complexity in the implementation of their water supply management.

When designing water supply systems for boiler houses, it is necessary to take into account the terrain, consumer requirements, water quality and tariffs for utilities provided. Small objects (villages, settlements, boarding houses, etc.) suffer from: less potential for savings when increasing the scale of production and lack of potential. Specific and operating costs in small settlements are approximately 50-100% higher than in large cities. At the same time, the ability to pay for services is significantly lower due to low per capita incomes. This leads to the fact that operating costs can significantly exceed operating income. As a result of this situation, in cities with a population of less than 100,000 people, the breakdown rate of utility systems is often higher than in large cities. In addition, in small towns, accident rates are growing much faster, which leads to accelerated deterioration of infrastructure.

In order to visualize the management of water supply systems and reduce costs in heating systems, it is proposed to introduce zoning of territories and waste heat recovery for the needs of boiler houses.

Quarter 76 was chosen as the object of research (Fig. 2). The purpose of the pilot project is to introduce a water supply and energy management system at the local boiler house, with a reduction in water and electricity losses, as well as constant monitoring of the supply and consumption of water resources. Experimental zones were used to determine, measure and reduce losses. When choosing an array, we were guided by the fact that the territory should contain all types of consumers; and that it has a high level of unpaid water and heat.

Figure 2. Scheme of the quarter 76

Metering devices were selected exactly according to consumption and calculated for average, maximum and minimum consumption.

Last year, water losses in the quarter amounted to 36% and the task was to significantly reduce leaks. The residential area consists of multi-storey buildings. Water supply and heat supply is carried out from the local boiler house. From pumps with a single water pressure for all buildings from 0.00 to 4.00 hours - 10.0 m; from 5.00 to 24.00 hours - 52.0 m. Previously, the control of water supply to the network of the quarter was carried out using metering devices (class B) installed in the boiler house and in the basements of residential buildings. A system was chosen with data transfer to the Internet, and then to the control system, mathematical and statistical data processing (Fig. 3).

During the experiments, it was proposed to divide the quarter into three zones, depending on the required pressure, and install “smart” meters. All this made it possible to quickly manage water consumption, heat supply and respond to leaks that occur on external networks, in house systems or as a result of water theft. The created database of consumers made it possible to calculate the nighttime minimum of water consumption (from 2 to 4 hours), which became an indicator of leaks in this area. Water savings according to research results amounted to 20% of the total monthly consumption. Water losses in the quarter after the implementation of the project amount to 15%.

Due to interruptions in the water supply, the use of additional sources (groundwater and storage tanks) is proposed.

The possibility of using two types of tanks is analyzed. Tanks located at sufficiently high elevations can serve as pressure (active) tanks, similar to water towers, since with the same capacity the tank is always much cheaper than the tower. Pressure tanks should be arranged in the form of “mountain” tanks wherever the terrain allows it, and where they will not pose a threat to the safety of the population.

The second type of tanks are non-pressure (passive), i.e., those from which water can enter the system only by pumping it with a pump. Tanks of this type are at the same time control tanks.

When solving water supply issues, it is necessary to take into account the size of the serviced area, the volume of water consumption, the water consumption regime, the required costs and pressures, the difference in geodetic marks and the qualitative composition of the supplied water.

The estimated method for calculating specific water consumption is methodologically imperfect, as a result of which the calculated values of specific water consumption differ significantly from the actual ones [13].

Figure 3. Data processing scheme

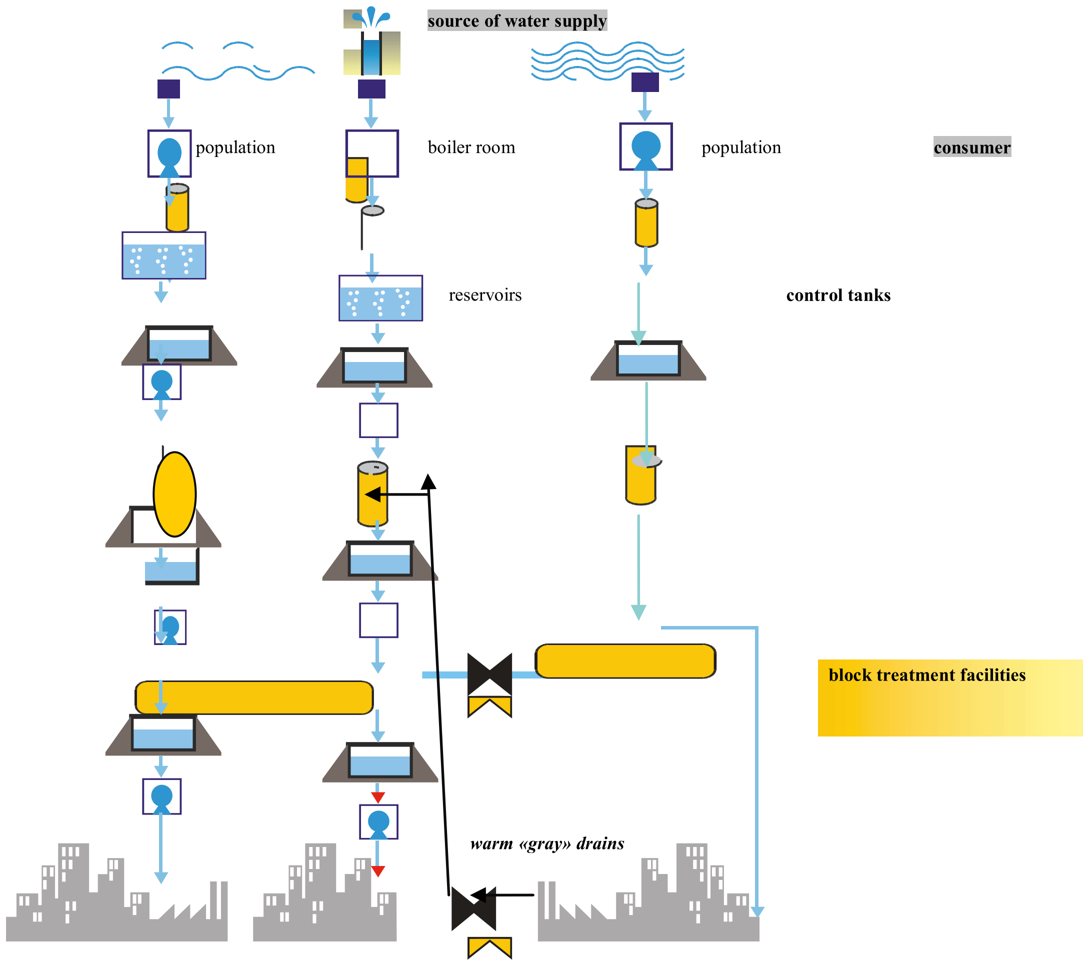


Figure 4. Structure of the water supply system

The tasks of rational operation and development of water supply systems are greatly simplified if any individual level can be distinguished from the general network. This is achieved by decoupling existing levels through various regulatory elements. At the same time, the structure of the water supply system for the boiler house and the population will take the form shown in Figure 4.

.An analysis of the values of specific water consumption shows that even with fairly approximate methods of calculation, the range of their fluctuations is very large. This is an indirect evidence of some uncertainty in the criteria for specific water consumption.

Refinement of the structure of water consumption makes it possible to detect a reserve - a theoretical value defined as the difference between the actual and ideal water consumption. For the full implementation of the reserve, it is necessary to create ideal conditions in the system, which requires significant material costs, and is impossible at the current technical level. But this does not reduce the importance of its definition, since the reserve allows you to detect opportunities for saving water when acting on different elements of the systems and determine a strategy to combat losses.

A clear example of the excess of standards over actual costs can be diagrams obtained as a result of studies of modern multi-storey buildings with centralized hot water supply after the implementation of a set of water protection measures (Fig. 4) [14].

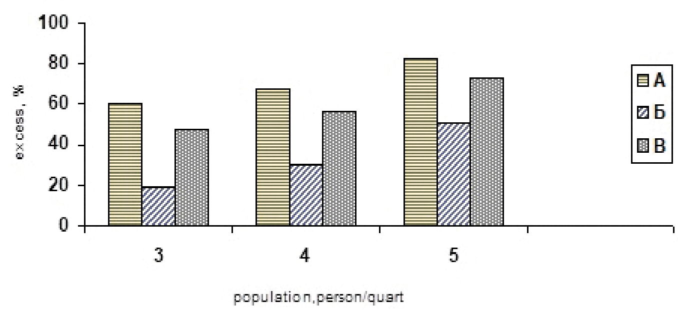


Figure 4. The excess of SNiP data over the actual average daily water consumption: A - for cold water; B - hot water; B - for total water consumption.

You can reduce the amount of water consumption by installing metering devices.

It has been established according to [15-18] that unproductive water losses increase the total water intake by 20-30%, water leaks in residential buildings - by 30-60%, and water leaks from networks - by 15-30%.

Each of these values has a different effect on the formation of the total water withdrawal from the networks for each of the calculated cases. Losses and leakages of water are the largest at minimum consumption, the smallest - at maximum, and unproductive losses - on the contrary.

Based on optimal water loss conditions, the formula for commercial programmatic loss management can be used by extrapolating the cost of a meter replacement program:

$$C_c = M \cdot N \cdot s / 2 \cdot y, \qquad (1)$$

where M is the average cost per meter replacement, including materials, labor, manufacturing cost, etc.

N - number of connections;

s - decrease in the accuracy of the counter per year;

y — commercial losses, %.

According to studies, the accuracy of small meters (size - 5/8) decreases on average by 0.5% per year. That is, after 5 years of use, the accuracy of metering devices will decrease to 95%.

The average annual cost of a meter replacement program can be determined by the formula:

$$C_m = M \cdot N / P_m \qquad (2)$$

where Cm is the average annual cost of the meter replacement program, rub/year;

Pm - meter replacement period, years.

Conditions that lead to the maximum optimal level of loss volume:

1) low level of consumption without a tendency to rapid growth;

2) large length of pipes of the distribution system per connection;

3) low average tariff;

4) the high cost of an active leak control program;

5) a sufficient level of expansion of investment activities and capital construction;

6) a large amount of losses caused by breakthroughs and leaks;

7) low variable cost of the filing process.

The first three parameters are the most sensitive.

It should also be noted that excess production capacity further increases unit costs.

At present, the “cost plus” tariff scheme is applied for the regulation of utilities sector enterprises. This means that, in addition to the cost of the service, businesses receive an agreed-upon fixed share of “profit”, which deprives them of the incentive to cut costs. An alternative to the “cost plus” scheme is the “price cap” tariff scheme, in which the regulator places a cap on the tariff on products that businesses can take from consumers.

It should be noted that even maintaining services at the current level requires significant financial costs from consumers and the state budget. Going beyond adequate service support would significantly increase the existing financial gap between investment needs and available funding. Key reforms to promote investment should be directed first to immediate projects and then to promising ones. Slowing down the processes of system optimization will lead to a deterioration in the quality of services or to their complete cessation. This situation is especially acute in small towns.

It should also be taken into account that hot water heating accounts for 20-25% of the total energy consumption in a typical home, and most of the load is for heating water for bathing or showering. The cost of hot water, as a rule, takes the second place in the column of expenses for housing and communal services in multi-apartment residential buildings, second in cost only to the costs spent on space heating. Studies have shown that 1/10 of the water used in the shower is sufficient for hygienic procedures. This means that about 90% of the warm water supplied to the shower faucet is drained into the sewer unused.

In addition to warm water from the shower, washing machines and dishwashers also contribute to heating water using electricity.

Recycling and reusing most of the wastewater energy will save heat energy and reduce the overall cost of hot water.

Wastewater has an average temperature of around 21–26 °C. The amount of wastewater is in direct proportion to the consumption of drinking water and for various types of buildings on weekdays averages from 200 to 330 l / day per person for residential buildings. The use of wastewater thermal energy makes it possible to achieve high rates of heat savings associated with the high influence of seasonal performance factors, as well as the environmentally friendly use of heat recovery systems in the house. One of the important factors in ensuring the efficiency of the system is the regular removal of the biofilm that forms on the part of the heat exchanger that is washed by the wastewater.

The wastewater temperature at collection points is approximately 10 to 15 °C throughout the year and even reaches 20 °C in summer, which is enough for guaranteed and trouble-free operation of heat pumps. During the winter months, when there is a high demand for thermal energy, the temperature of the waste water in the places of centralized installation of heat pumps is only about 10 °C, which leads to a decrease in the efficiency of the heat pump.

In order to determine the energy potential of wastewater, it is necessary to know the consumption of cold drinking water, as well as the temperature of the wastewater, these values must be measured at control facilities. It is assumed that the consumed amount of drinking water is equal to the amount of wastewater discharged from the building. Wastewater temperature is measured respectively by two temperature sensors in each sewerage system. Measuring points are located on the main main sewer pipes and before the discharge of wastewater into the external sewer system (Fig. 3).

Typical daily changes in drinking water consumption and wastewater temperature on weekdays, based on the arithmetic mean value for one of the houses in block 76, are shown in

Fig. 5-7.

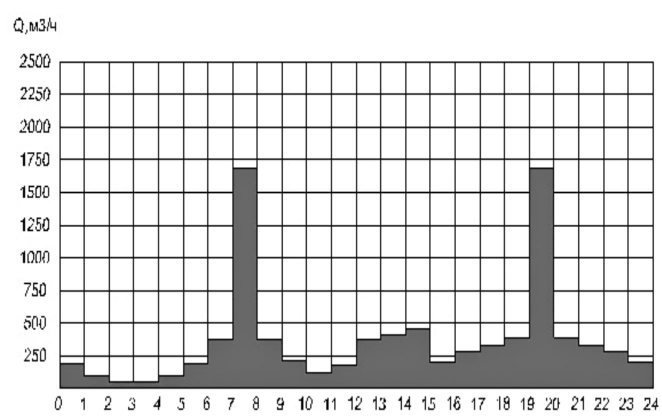
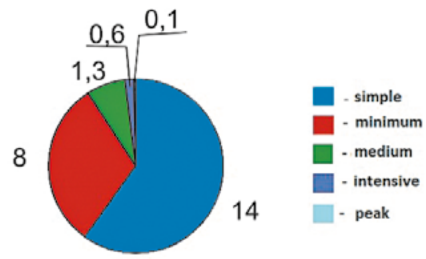
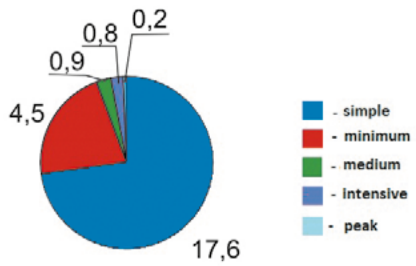


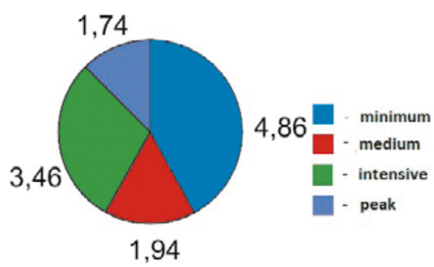
Figure 5. Graph of the average daily water consumption for the building



A) duration of water consumption mode, hour



B). Duration of the regime during the maximum water consumption



C). Volume of water during maximum water demand

Figure 6. Water consumption mode

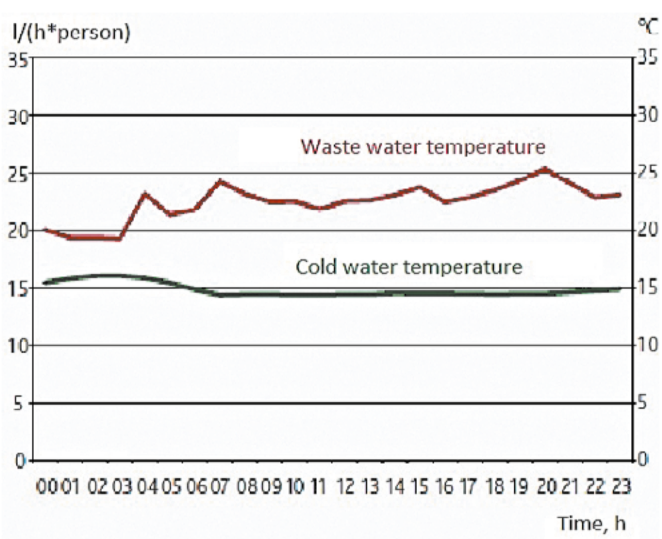


Figure 7. Change in temperature during the day

Due to the high temperature level, wastewater can be classified as an ideal heat source for a heat pump system. The wastewater storage tank compensates for fluctuations in the amount of incoming wastewater during the day and at the same time serves as the installation site for a one-way heat exchanger that absorbs heat from the wastewater. The heat pump transfers the received thermal energy to the heat exchanger, which serves to heat the water. The system is designed for two-stage water heating: the heat pump preheats drinking water, after which the second heat generator (for example, a conventional gas boiler) raises the temperature of the preheated water to the temperature required for hot water supply - 60 °C. This is done in order to prevent the growth of bacteria and to ensure the hygienic requirements for DHW systems.

Due to the saturation of the nutrient medium of the wastewater, as expected, the formation of biofilms occurred on all contact surfaces

The study showed that in order for the system to work effectively, it is necessary to reduce the formation of biofilm on the part of the heat exchanger that comes into contact with wastewater, for example, using innovative and automated cleaning methods. wastewater heat recovery directly in the building can be considered as a promising technology that allows increasing the energy and resource efficiency of heating devices in buildings.

In most cases, as mentioned earlier, energy costs at boiler houses are also related to the quality of the source water and require the installation of treatment facilities (Figure 8).

Figure 8. Water treatment station for a boiler room

Conclusions. The proposed control system for the water supply system of the boiler house provides for the zoning of territories, the identification of real consumption rates, and the accounting of consumption using smart meters.

Pilot studies show that as a result of targeted management of the system, it is possible to reduce water losses (by 20% within the framework of the project) and use the technological reserve for upgrading systems, taking into account wastewater heat recovery.

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