The management system of water supply in the cities of Donbass

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Abstract. During more than twenty years, survey of water supply systems in the cities of Donbass was conducted. The aim of the study was to develop a strategy for managing this sector, which allows for precise monitoring of water consumption and reducing water loss. In the course of the research, water consumption metering was carried out using counters, the operation of the devices was assessed taking into account the accuracy class and installation features. It is established that the actual value of water consumption is below the standard. The water consumption decreases with an increase in the percentage of installation of water meters and with an increase in the number of tenants in an apartment. The need to bring the general house and intra-apartment meters to the same accuracy class and regulate the installation position of the water meter was identified. Based on the optimization of conditions, the program management of water supply systems by means of zoning territories and the installation of "clever" meters was proposed. Approbation of the water supply management strategy allowed within the project to reduce water losses by 20% and use the technological reserve for the modernization of the water supply system.

1 Introduction

The water supply systems of cities on the specific character of functioning and designation relate to the complex technical systems of queueing. The contemporary engineering methods of creation and operating such systems are based on the active attraction of the quantitative methods of analysis and synthesis of their reliability. Disruption of the work of system is caused by different random events. The only way of evaluating the possibility of the appearance of such events is collection and processing the statistical evidence about the work of the operational systems. This information makes it possible to establish the numerical authenticity of the appearance of the random events, which can lead to the disturbance of the normal functioning of separate elements. Today the reliability of the operational water-supply systems is ensured by the redundancy of elements, by effective

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organization of their operation and by goal-directed control of the processes, which take place in the systems.

2 Methods

The inspection of the water-supply systems of the Donbass cities was carried out for several years. On the basis obtained given is carried out monitoring and the system of the zoning of cities is developed. The approval of the control of the water supply to population is executed in the territory of several regions. Effectiveness from the use of this system – 20% of the savings of resources.

Scope by municipal water supply in Donbass sufficiently high. The part of the users, connected to the network of the municipal water supply, varies from 26% (for the rural locality), also, to 83% (in the city).

In recent years the demand for the water of the enterprises of municipal service system significantly was reduced (on the average from 1990 the year in 2-3 times).

In some places it was reduced triply, in connection with reduction in the industrial water consumption, by failure of the hot water supply and by control of demand with the aid of the counters.

Population is today the basic user of water for any populated area, therefore it is at present very important to have the precise information about the size of the drinking water consumed by inhabitants.

According to the data of systematic observations, the average value of the specific daily consumption of water in the habitable buildings in 1971, 1977 and 2017 years it comprised respectively 200, 240 and 306 l/(day·person), whereas in other countries by standard it is considered 150-200 l/(day·person). [1-3].

The scarcity of drinking water today feels a number of cities and villages. Therefore it is necessary to consider the minimum standard of water consumption, which is composed of, [4]: health and hygiene; design; commercial and operational norms.

Health and hygiene standards are determined on the basis the physiological and hygienic needs of man and can depending on region comprise from 30-60 l/day.

Design standards characterizes a maximally possible level of the consumption of water, on the basis which is calculated the productivity of water-supply systems. Under the actual conditions specific expenditure can be higher than it regulates within the construction standards [5], because of inaccuracies in calculation or incorrect forecast of other values, in particular population. For the same reason into some regions will be observed the surplus of water, and in others – scarcity.

The commercial standards, which are established for the contra accounts, regulate the organs of local self-guidance, in this case they must consider the special features of this locality – climate, tradition, the level of culture, health and hygiene requirements.

Operational standards are the rational delivery volume and consumption of production with the actually attainable level of reduction in the unproductive losses.

The estimated method of calculating the specific water consumption exists in the systematic sense in terms of that not perfected, as a result of which the calculated values of specific water consumption they are considerably differed from the actual [1].

By the basic reason for distortion is the insufficient consideration of demographic situation, which determines an actual quantity of users by the services of the centralized water-supply system of city, and the structural special features of consumption the different categories of water consumers.

The analysis of the values of specific water consumption shows that even with the sufficiently approximate calculation methods the range of their fluctuations of completely large. This is indirect evidence of a certain uncertainty of criteria of specific water consumption.

The refinement of the structure of water consumption makes it possible to reveal reserve – the theoretical value, defined as the difference between the actual and ideal water consumption. The necessary creation of ideal conditions in the system, which requires significant material expenditures, and at the existing technical level is impossible for the complete realization of reserve. But this does not decrease the importance of its definition, since the reserve makes it possible to reveal the possibilities of the savings of water under the effect on the different elements of systems and to determine strategy of fight with the losses.

3 Results and Discussion

For determining the reserve of household drinking water supply it is necessary to know the ideal water consumption, which is determined by the need of man for the water for conducting of health and hygiene procedures and economic processes in the dwelling. the Economic- hygienic need for the water is determined on the basis of analysis and working data by medico- hygienic studies and on the average is 75,6 l/(day·person), and in the social need is considered the influence of climate (about 111,3 l/(day·person)). The need for the water realizes in the process of the use of water pipe. In this case the losses of water appear and actual water consumption considerably exceeds need, reaching to 300-500 l/(day·person). For social the need mentioned above the reserve of water pipe is 200-400 l/(day·person) depending on magnitude of losses, determined by the technical state of system. As the obvious case of exceeding the norms above the actual consumptions can serve the diagrams, obtained as a result of studies of the multistory buildings (more than 12 floors) of contemporary improvement with the centralized hot water supply after the realization in them of the complex of water-guarding measures (Fig. 1) [6].

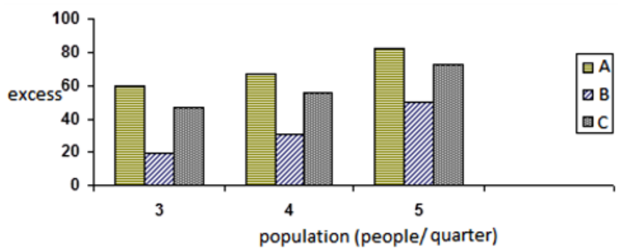

Fig. 1. Exceeding the data above the actual average-daily consumption of the water: A - the cold water; B - the hot water; C - the general water consumption.

To decrease the value of water consumption is possible due to the installation of the instruments of calculation.

In recent years the percentage of users with the instruments of calculation increased to 86%.

For the purpose of the determination of the actual standards of water consumption was conducted also the inspection of the water-supply systems of the regulated dwelling of Donbass. In the course of inspections there were the selected buildings with the different degree of improvement. Were examined, both particular house ownerships and two-, five-, nine-story buildings with the public-housing water meters. The results of studies are given in the (Fig. 2).

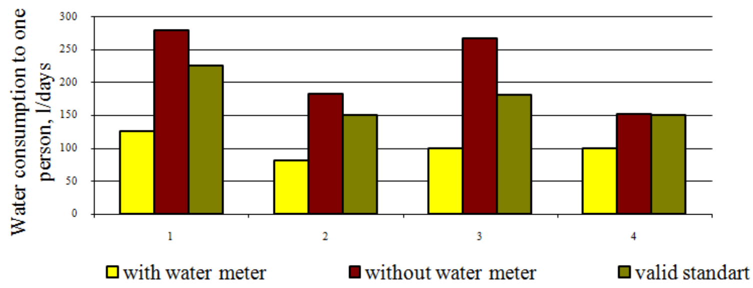

Fig. 2. Comparative analysis of in force norms with the existing water consumption in particular house ownership: 1 - with the water pipe, the canalization or the cesspool, equipped with gas stoves or electric stoves (225 l/(day·person)); 2 - with the water pipe, without the canalization, without the baths (150 l/(day·person)); 3 - with the water pipe, the canalization, the cesspools, the kitchen center without the gas supply / the same with the presence of titanium on the solid fuel (180-230 l/(day·person)); 4 - with the supply of drinking water from the yard columns (150 l/(day·person)).

The comparison of current standards with the real water consumption by one family gives the analogous results: is observed reduction in the general water consumption by family with an increase in the composition of those living, and also exceeding in force norms. For the purpose of the development of difference there were the conducted investigations in the houses with the public-housing and apartment counters. The results of studies are given in the table 1.

Table 1. Analysis of water consumption on the many-storeyed houses.

Address	Water consumption, m^3/month			the losses of waters, which are connected with the class of the precision of the counters	% the losses, which are connected with the class of the precision of the counters
	tern	from the indications of the public-housing counters	sum of the indices of the individual of the counter		
Central st., 22	September	37	20	17	45,9
	October	33	23	10	30,3
Simonenko st., 28	September	185	180	5	2,7
	October	250	180	70	28,0
Protsenko st., 23	September	81	55	26	32,1
	October	60	57	3	5,0
Protsenko st., 25	September	108	41	67	62,0
	October	60	59	1	1,7
Mira st., 15	September	106	104	2	1,9
	October	119	72	47	39,5
Simonenko st., 4	September	169	91	78	46,2
	October	139	104	35	25,2

Obtained data testify about the need of bringing the counters to one class of precision. Each water meter, independent of its type has limitations with the measurement of expenditure and specific magnitude of losses of water. To the basic factors, which influence instrument accuracy can be attributed: the regime of the water supply, the metrological class of water meter and the assembly position of counter. In the course of studies were selected 4 apartment of the counter of different classes the accuracy with the nominal consumption 1,5 of m^3/h. The results of studies (table 2-3) confirm that not each water meter has identical threshold of response depending on factors enumerated above. For the purpose of the decrease of the magnitude of losses of water and guarantee of the accuracy of calculation it is necessary to select the water meter of the highest class of precision and to determine the optimum assembly position for it.

With the determination of the standard of water consumption it is necessary to focus attention on the losses of water in the houses. The consequence of the losses of water in the apartment houses is the excess value of the specific water consumption of population, which in 1,5-3 time is greater than in the countries of Western Europe. Established [7-20], that the unproductive losses of water increases the general selection of water by 20-30%, the water leaks in the apartment houses - to 30-60%, and the water leaks from the water-conducting networks - on 15-30%.

Table 2. Influence on the accuracy of the measurement of the class of water meter and assembly position (horizontal).

Type of the water meter	Class of the precision	Water consumption				
		the initial counter readout, m^3	the final counter readout, m^3	expenditure, m^3	deviation in the comparison with the water meter of the type 820 Sensus	
					absolute, m^3	relative, %
820 Sensus	C	1,444	60,094	58,650	0,000	-
JS 1,5 NK Apator	B plus	1,150	59,910	58,760	0,110	0,19
KB-1,5i	B	2,269	58,129	55,860	-2,790	-4,76
Residia Jet Sensus	B	61,858	116,068	54,210	-4,440	-7,57

Table 3. Influence on the accuracy of the measurement of the class of water meter and assembly position (vertical)

Type of the water meter	Class of the precision	Water consumption				
		the initial counter readout, m^3	the final counter readout, m^3	expenditure, m^3	the initial counter readout, m^3	
					absolute, m^3	relative, %
820 Sensus	C	62,334	118,984	56,650	0,000	-
JS 1,5 NK Apator	A plus	62,080	114,480	52,400	-4,250	-7,50
KB-1,5i	A	60,169	111,049	50,880	-5,770	-10,19
Residia Jet Sensus	A	118,058	166,628	48,570	-8,080	-14,26

Each of these values has a different effect on the formation of the total water consumption from water mains for each of the design cases. Losses and leakages of water are greatest with minimum water consumption, are smallest with maximum water consumption, and unproductive losses - on the contrary. Based on the optimal conditions of water loss, can use the formula for commercial programming control of water losses by extrapolating the costs of the water meters replacement program:

$$C_c = M \cdot N \cdot s / 2 \cdot y \text{,} \quad (1)$$

M - the mean cost on the replacement of counter, including materials, labor expense, the cost of production and, etc;

N - a quantity of connections;

s - reduction in the accuracy of water meter per year;

y - commercial losses, %.

According to studies the accuracy of small water meters (size – 5/8") on the average is reduced on 0.5% in year. After 5 the years of use the accuracy of water meter will be lowered to 95%.

The mean yearly cost of program on the replacement of counters can be determined according to the formula:

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

C_m - the mean yearly cost of program on the replacement of counters, hrn/year;

P_m - the period of the replacement of counter, years.

The conditions, which lead to a maximally optimum level to the volume of the losses: the low level of consumption without the tendency toward the exuberance; the large length of the pipes of the distribution system of water supply to the connection (with the condition of the low density of population); low mean tariff; the high cost of the program of active monitoring over leakages; a sufficient level of the expansion of investment activity and of capital construction; the large volume of the losses of waters, reason for which are breakthroughs and leaks; the low variable cost of the process of the water supply into the water-supply system (electricity and the chemical reagents). The first three parameters are most sensitive.

It should also be noted that the surpluses of production capacities (as a result drop in the demand for the water by industry) additionally increase specific expenditures.

At present for the regulation of the enterprises of the sector of water supply adapts tariff diagram “expenditure plus”. This means that into the addition to the cost of the service of enterprise is obtained the matched fixed particle “of profit”, which deprives of their stimulus to reduce expenditures. By alternative to diagram “expenditures plus” are a tariff diagram “upper level of the price”, with which regulation organ establishes upper boundary of tariff on the water, which the enterprises can take in users. It is necessary to note that even support of the services of water supply at the existing level requires significant financial expenditures from the side of users and budget. If we leave beyond the framework of the support of services at the proper level, this will substantially increase the existing financial break between the investment needs and the existing financing. Basic reforms for the assistance to investments must first of all be directed to urgent projects and then to the promising. Retarding the processes of reformation will lead to worsening in the quality of services or to their total curtailment. Especially sharply this situation is outlined in the small cities.

Small and medium-size cities suffer from: smaller potential for the savings with an increase in the scales of production, low incomes of population, lack of potential and access to markets for capital. Specific and operating costs in the small and medium-size cities are by approximately 50-100% higher than in the large cities. At the same time, the ability to pay services is considerably lower than in the large cities because of the low incomes per capita of population. This leads to the fact that the operating costs can considerably exceed incomes from the basic activity. As a result this situation in the cities with the population is less than 100 000 people the accident rate of systems frequently higher than in the large cities. Furthermore, in the medium-size and small cities the coefficients of accident rate grow considerably more rapidly, which leads to the accelerated wear of infrastructure. For the purpose of the visualization of control of the water-supply systems and reduction of expenditures in the sector it is proposed to inject the zoning of urban territories. Such projects began to successfully take root. Let us examine one of them.

As the subject of studies was selected 276 district. By the purpose of pilot project is the introduction of control system water-conducting economy, with reduction in the losses of water, and also a constant control of delivery and consumption of the available water resources. Experimental zones were used for the definition, the measurement and abridging the losses. With the selection of massif they were oriented toward the fact that the territory must contain all types of users; and so that in it there would be the high level of unpaid water. Zone must be supplied of one inlet, but water from it must not be exported to other regions (Fig. 3).

The instruments of calculation were selected accurately by the expenditure and were calculated for average, maximum and minimum consumption.

In 2017 the water loss on the district comprised 36% and the task considerably decreasing leakages was set. Residential area consists of 12-, 9- and the 2-storey building. Water supply is achieved from the pumping plant which located in TSTP of district, from the pumps with the united pressure of water for all buildings (the 2-, 9-, 12 floors) from 0.00 to 4.00 hours – 10,0 m; from 5.00 to 24.00 hours – 52,0 m. The previously control of the water supply in the network of district was performed according to the instruments of calculation (class c), established in TSTP and in the basements of apartment houses. Was selected system AMIPro with the transmission of data to the Internet, and further into the system of control, mathematical and statistical processing of data (Fig. 4).

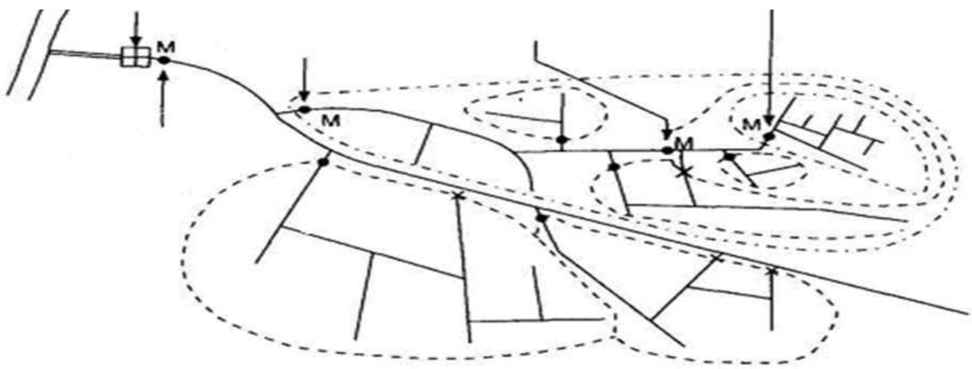

Fig. 3. Supply area diagram

Fig. 4. Diagram of processing data of the control of the expenditures of water.

In the course of experiments it was proposed to divide block into three zones, depending on the necessary pressure, and to establish “clever” counters. All this made it possible to operationally govern the water consumption of block and to react to the leakages, which appear on the external networks of water line, in the intra-house systems or as a result the embezzlement of water. The created base of users made it possible to calculate the night minimum of water consumption (from 2 to 4 hours), which became the indicator of leakages in this zone. The savings of water according to the results of studies comprised 20% from the total monthly volume of consumption. The losses of water in the block after the introduction of project comprise – 12%.

4 Conclusions

The most significant results of this study include:

– the results of mathematical statistical analysis of research data showed a tendency observed in recent years to shift water consumption to minimum values and a decrease in actual water consumption in comparison with the standard;

– the percentage of consumers with water metering devices in the Donbas reached 86%;

– found that increasing the number of people in a family leads to a decrease in specific water consumption. With a family of 4 people, specific water consumption is three times less than in a family for 1 person;

– disagreements were revealed in the indicators of general house and intra-apartment meters (up to 62%), which indicates the need to bring them to the same accuracy class or requires the introduction of amendments;

– the main factors affecting the accuracy class of water meters include the water supply mode and the assembly position of the unit;

– water losses and leaks have maximum value with minimum water consumption;

– the proposed water supply management system of the city provides for zoning of territories, identifying real water consumption norms, and water metering using "clever" meters. Pilot studies show that as a result of targeted management of the system, water loss can be reduced (within the project - by 20%) and the technological reserve can be used to modernize water supply systems.

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