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Improving the heating networks efficiency by implementing instrumental methods of control

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Abstract. Problems of increasing the reliability and efficiency of heating networks operation are closely related to the reduction of costs for the repair and restoration activities. The high cost of installation and emergency restoration work in the conditions of a shortage of funds dictates the need to develop and implement new methods of maintenance. Diagnostics of heat networks allows to determine their technical condition, to identify the most decrepit sections of pipelines for the purpose of repair work.

1 Introduction

In accordance with the Energy Strategy of Russia for the period up to 2035, the priority areas for the development of the country's economy energy sector are the creation of highly efficient energy systems and complexes and an increase the use efficiency of the energy resources in energy-intensive industries.

Due to the high deterioration of energy facilities, their modernization is one of the key issues for shifting the Russian economy to the path of innovative development. Energy saving issues are of particular importance and become priorities for all enterprises.

There is about a third (29 %) of heating networks in a state of usage factor in Russia. To ensure reliable heat supply, 4–5 % of pipelines need to be updated annually. There is lack of funds for it [1].

Chronic underfunding of the heating industry leads to social tensions. There are often breakthroughs of heating pipes occurring in winter. Tens of thousands of people remain without heating in the cold. For example, in early 2019 in Barnaul, heating and hot water supply to 224 residential buildings, 17 social facilities and 29 administrative buildings ceased. Earlier, even more large-scale accidents occurred in Samara and Tver, where trunk pipelines broke through. Work on the replacement of decrepit heating networks should be conducted annually. Only such an approach will allow the equipment to be maintained in working condition [1].

2 Analysis of problem

Based on the analysis of the heat supply industry state, it follows that increasing the reliability of the centralized heat supply systems is one of the urgent scientific and practical tasks of developing the country's energy sector.

The weakest link of the heat supply system is the heating network. Damage to heating networks, despite the increase in the volume of changes in recent years, remains at a high level.

Major accidents, as well as an increase the damageability of underground heat pipelines, lead to significant overspending of thermal energy and fuel, additional investments, and high human labor costs.

The studies conducted by the authors showed that the amount of damage to heating networks elements is on average from 20 to 40 pieces per 100 km of the route and increases with the increasing pipeline period of service. Table 1 presents the average data on the heating networks damageability of Kazan for 4 years.

Table 1. Average damageability of heating networks of Kazan.

Pipelines	Average damageability for 4 years
Trunk	490
Quarter (heating)	1581
Hot water supply	967

During the damage analysis, the main causes of the incidents were highlighted:

- defect of valves;
- hole;
- external corrosion.

Since the level of deterioration of heating networks in our country is very high, it exceeds 70%, in some regions, while there is a lack of funding. For this reason, a complete reconstruction is often impossible. Therefore, the choice falls in favor of local repairs.

In order to carry out repair work, diagnostics of heating networks is carried out, which allows to determine their condition, select the most decrepit and potentially dangerous pipelines sections.

Diagnostics of pipelines is carried out in order to obtain data on:

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- locations, level and degree of danger, from the standpoint of leakage, corrosion damage to the metal of pipes - such defects as thinning of the pipe wall from internal and/or external corrosion by more than 30% of the nominal value;

- detection of the location of heat carrier flow (leakage);

- factors causing the intensification of corrosion processes at the site (stray currents, silting and flooding of channels, etc.).

Currently in Russia, the most common methods for diagnosing heating networks pipelines of underground installation are [2, 3]:

- testing of pipeline sections for density and strength in accordance with the technical operation rules by creating a pressure inside the pipe of at least 1.25 from the operating one;

- a method of soil excavation with the opening of the engineering network channel, which is widely used in the search for defects during operation or after conducting scheduled tests of heating networks. This method is governed by the instruction for heating networks [7] and is based on an external examination of building structures and the state of thermal insulation materials and the pipeline.

Monitoring of the heat pipelines metal state without opening the heating mains is carried out in isolated cases, on the main pipelines. The cost of such an examination for many companies is extremely high.

The task of searching a pipeline defect and determining the cause of its occurrence occupies a special place. And not only the time to limit the supply or transmission of heat, traffic and pedestrians depends on its solution, but also the costs associated with the volume of ground works and subsequent improvement to restore the damaged landscape of the area.

3 Method of solving

One of the ways to solve the improving the efficiency of heat supply is the transition to the creation of a monitoring and diagnostic system with the subsequent formation of a system for the major repairs of heating networks. The basis of this system is the automated control of the pipelines and technical equipment state.

Analysis of methods for determining the state of heating networks showed two main directions for solving the problem:

1. Carrying out the control of heat pipelines by instrumental methods.
2. Prediction of damage and assessment of the reliability of heating networks based on statistical methods.

Detection of leaks from pipelines is a difficult technical problem, the solution of which requires special equipment. The main control methods are: acoustic, correlation, thermal.

An integrated approach to solving the problem of detecting water leaks from a pipeline using instruments significantly increases the accuracy of detection of an emergency site. At the same time, the use of diagnostic methods determining the condition of the pipeline should help identify potentially dangerous hydrogeological areas. It would justify the need for additional waterproofing, drainage, insulation of channel overlaps, and the possibility of developing ways to efficiently ventilate them to dry insulation plating and prevent condensate from falling out.

However, in the conditions of market economy it is important to provide a feasibility study on the efficiency of the heating networks reconstruction, because the final result is investment in the construction of the facility and, as a consequence, operating costs. There is a need to determine not only the reliability of the system, but also the effectiveness of the system.

The basis for ensuring the reliability of heating networks is the knowing of the real state of their elements. It ensures efficient use of resources for ensuring operability. Until recently, repair and relaying of heating networks were often carried out according to the service life and depreciation rate. However, the condition of heating networks elements depends on the specific conditions of their operation, which can both accelerate and slow down their destruction, which leads to satisfactory reliability of elements with high depreciation usage.

4 Results

Nowadays, there are several basic approaches that allow in practice to assess the effectiveness of the implementation of diagnostic methods. Economic efficiency consists of direct and indirect saving. Direct saving can be attributed to reduced equipment repair costs, an increase the real turnaround time due to the exclusion of scheduled repairs. In addition, it also reduces the cost of repair by identifying defects, the elimination of which does not require dismantling. Indirect cost saving is due to lower costs that are not directly related to production costs (losses incurred as a result of unplanned downtime of equipment, release of defects, as well as the costs of eliminating accidents).

Table 2. Calculation of the cost of replacing 1 l.m. pipeline in traditional insulation.

Diameter	Cost, rubles	Diameter	Cost, rubles	Diameter	Cost, rubles
57	7031	159	10219	530	25993
76	7485.6	219	12946	630	33475
89	7968.8	273	15865	720	37706
108	9112.5	325	20292	820	48021
133	10003	426	22517		

There is the cost of replacing 1 l.m. pipeline in traditional insulation of different diameters in Table 2. During calculating the cost, the costs include restoration works (chernozem dumping, grass sowing, planting trees, restoring small architectural forms, etc.), cutting and adding soil during planning, as well as dismantling and paving works.

The damage volume depends on the time of the recovery period, that is, the time taken to detect and repair the damage, as well as to restore the heat supply. Usually this time is measured in hours and sometimes in dozens of hours.

As a rule, damage to heating networks leads to significant material damage, estimated at tens of thousands of rubles. The average cost of replacing 1 linear meter pipeline, depending on the heating networks damageability, is presented in Table 3.

Table 3. The average cost of replacing of 1 linear meter pipeline.

Pipelines	The average cost of replacing, rubles
Trunk	16435765.99
Quarter (heating)	20668144.05
Hot water supply	7247785.392

The total economic efficiency of using non-destructive testing methods in heating networks can be calculated using the following universal formula:

$$E = \sum_{i=1}^{n} (Z_{i1} - Z_{i2}) \quad (1)$$

where i – serial number of factor taken into account, n – the whole number of factors taken into account, Zi1 and Zi2 – cost of effect of i-factor before and after the implementation of diagnostic methods and tools, respectively.

The results of calculations for the control of heating networks are presented in Table 4.

Table 4. Costs for control.

Pipelines	The average cost for control, rubles
Trunk	1666000
Quarter (heating)	5375400
Hot water supply	3287800

The data on the cost of monitoring and eliminating accidents for trunk and quarter pipelines and hot water supply networks are presented on the histogram of fig. 1.

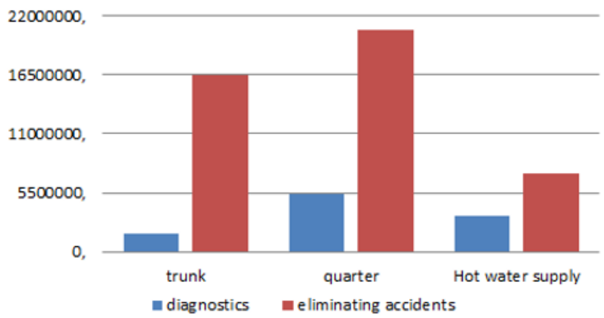

Fig. 1. Cost to control and accident elimination.

During determining the exact location of a defect or leak, it is possible to minimize the volume of groundwork. A timely monitoring allows you to send the funds scheduled for repairs to where the accident is more likely to occur.

5 Conclusion

Conducting engineering diagnostics in the winter period allows you to more efficiently prepare for the repair and restoration works in the summer period.

The ranking of the areas to be relayed according to the results of the control allows reducing the number of leaks during reducing the volume of relays. Information on the intervals ranked as areas of the worst condition and preventive maintenance of works on them also contributes to reducing the number of leaks. High accuracy of detection of damage to pipelines significantly reduces the time spent on detecting bursts of heating networks, reduces the cost of eliminating

Table 5. The results of the heating networks pipelines inspection in pitting locations.

Pit locations	Held pitting			Recognized fit heating networks pipelines			Rejected heating networks pipelines		
	Amount	%	Costs, rubles	Amount	%	Costs, rubles	Amount	%	Costs, rubles
On asphalt	23	20.5	158217	6	23.1	41274	17	73.9	116943
On asphalt-lawn	5	4.5	34395	1	20	6279	4	80	27516
On lawns	84	75	177927	52	61.9	111384	32	38.1	68544
Total	112	100	372540	59	53.7	159537	53	47.3	213003

them. Each leak accurately detected through instrumental control avoids an average of 2 pits.

The economic efficiency of instrumental control of pipelines can be seen on the example of carrying out planned pits, the results of which are presented in Table 5.

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