The impact of monitoring the state of heating networks on their effectiveness

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Abstract. The tasks of improving the efficiency and reliability of the operation of heat and
power equipment are associated with the renewal of fixed production assets and a reduction in
the cost of carrying out repair and restoration activities. The increase in the cost of repair and
maintenance, spare parts, installation and emergency repair work in the context of a shortage of
funds dictates the need to develop and implement new maintenance technologies. In this
regard, scientific developments aimed at improving the methods and means of assessing the
technical condition of thermal power equipment are relevant.

1. Introduction
Currently the issues of operation of underground engineering networks are widely discussed. For
enterprises involved in the transport of heat, hot and cold water in urban environments, the solution of
this problem is difficult.

Damage sites in underground sections of heating networks that appear in the process of density
testing of pipelines are usually found on the second or third ground piling. Heavy equipment is used to
perform the shafts, each hour of work is not cheap. Taking into account the cost of restoring building
structures and sealing the canal, backfilling and carrying out measures to restore the landscaping, it
turns out to be very expensive. The cost of these goals today for the city "millionth" is tens of millions
of rubles a year.

Thus, the task of finding a pipeline defect and determining the cause of its occurrence occupies a
special place and not only the time for limiting the supply of thermal energy, 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 terrain.

Enterprises operating hundreds of kilometers of underground pipelines and building structures for
their proper maintenance should:
- be able to systematically monitor the equipment in order to timely prevent its possible damage or
destruction;
- determine, with an accuracy of at least 1 m along the length of the channel, the place of damage during the period of scheduled testing or during operation, with a view to their prompt elimination;
- predict the time and place of possible occurrence of damage.

2. Methods
The operating organizations use a set of diagnostic devices and instruments, but resource-saving technologies are of particular relevance, allowing to reduce the time of work and save labor resources. Currently in Russia, the most common methods for diagnosing pipelines of underground heating networks are [2, 3]:
- testing of pipeline sections for density and strength in accordance with IPS by creating a pressure inside the pipe of at least 1.25 from the worker;
- an acoustic method, using which by means of vibro-acoustic sensors and further processing of their signals on a computer, the degree of wear of the pipe wall is determined or the location of the damage is carried out [4]. Restrictions on the application of the method: the length of the pipeline section being diagnosed is from 40 to 200 m, averaging the wall thickness along the pipe perimeter, the flow of heat carrier in the pipeline is necessary (up to 4 m³/ min);
- method of magnetometry using an in-line flaw detector, which determines the continuity of the metal [5]. About 98% of the defects detected by this method are confirmed after opening the channel. The difficulties of applying the method include the need to dig, drain the heat carrier and dismantle a part of the pipeline;
- a method of ground excavation (piling) with the opening of the channel of the engineering network, which is widely used when searching for defects during operation or after conducting scheduled tests of heating networks. This method is governed by instructions for heating networks [6] and is based on an external examination of building structures and the state of thermal insulation materials and the pipeline. At the same time, samples of soil and heat-insulating material are taken, which are then investigated in laboratory conditions. At the site of ground excavation (piling), measurements of the "pipe-to-ground" potential are carried out. On damaged sections of pipelines, a metal segment can be cut for laboratory research on the causes of damage (external or internal corrosion, the actual thickness of the pipe wall, the quality of the metal structure and its compliance with the allowed gauge for this engineering network, safety margin and maximum pressure on strength).

3. Results
In Yoshkar-Ola monitoring of the state of the trunk and distribution heating networks was implemented (Fig. 1). The monitoring showed that on the dilapidated heating networks outbursts occur both in the process of conducting hydraulic tests and immediately after being put into operation. The number of outbursts after start-up is up to 50% of the number of outbursts in the process of conducting hydraulic tests. To identify future impulses, it is not necessary to use hydraulic tests; acoustic control can successfully cope with this. Acoustic engineering diagnostics of pipelines replaces hydraulic tests and reduces the stress state of the metal caused by them. [6].

4. Discussion
Carrying out engineering diagnostics in the winter period makes it possible to more rationally prepare for the repair and rehabilitation works in the summer period.

The use of the method of acoustic tomography of pipelines and the ranking of sections that are put into a relaying based on the results of diagnostics can reduce the number of leaks while reducing the volume of relays. Information on the intervals ranked as areas of the worst condition and preventive maintenance works on them also contributes to reducing the number of leaks. The high accuracy of detection of damage to pipelines significantly reduces the time spent on detecting impulses of the heating networks, reduces the cost of eliminating them. Each leak, accurately detected by a leak detector, avoids an average of 2 ground excavations.
The economic efficiency of acoustic diagnostics of pipelines can be considered on the example of Yoshkar-Ola city. In 2004, 286 acts of visual measuring and ultrasonic testing of heating networks pipelines were made: heat chambers, channels, pits. The economic effect of the use of instrumental control can be estimated by:

1. Elimination of unsystematic (blind) ground excavations.

In 2004, 112 pits were surveyed. The results of the survey of heating networks pipelines only in the pits are presented in Table 1.

From the above data it follows that the results of visual measuring and ultrasonic testing of heating networks pipelines: 53.7% of all ground excavations were found to be suitable. These are mainly pipelines of the planned ground excavations. Thus, carrying out planned unsystematic (blind) ground excavations is not effective and not economical, because does not reveal critical areas. It is only necessary to plan the carrying out of ground excavations based on the results of engineering diagnostics.

**Figure 1.** Monitoring scheme of heating networks in Yoshkar-Ola.

**Table 1.** The results of heating networks pipelines survey in the places of ground excavations.

| Pit locations     | Ground excavations carried out | Heating networks pipelines found eligible | Heating networks pipelines condemned |
|-------------------|--------------------------------|------------------------------------------|-------------------------------------|
|                   | Amount | %      | Costs, rub. | Amount | %      | Costs, rub. | Amount | %      | Costs, rub. |
| On the asphalt    | 23     | 20.5   | 158217      | 6      | 23.1   | 41274       | 17     | 73.9   | 116943      |
| On the asphalt-grass | 5     | 4.5    | 34395       | 1      | 20     | 6279        | 4      | 80     | 27516       |
| On the grass      | 84     | 75     | 177927      | 52     | 61.9   | 111384      | 32     | 38.1   | 68544       |
| Total             | 112    | 100    | 372540      | 59     | 53.7   | 159537      | 53     | 47.3   | 213003      |
Table 2. The amount of heating networks pipelines damages in Kazan for 2013-2016 years.

|                                      | Pipelines          | 2013 year | 2014 year | 2015 year | 2016 year |
|--------------------------------------|--------------------|-----------|-----------|-----------|-----------|
| **Heating season:**                  |                    |           |           |           |           |
| **January-May**                      |                    |           |           |           |           |
| Trunk                                |                    | 11        | 4         | 6         | 5         |
| Quarterly (heating)                  |                    | 84        | 91        | 87        | 128       |
| Supplying hot water                  |                    | 119       | 77        | 84        | 85        |
| **Pressure testing**                 |                    |           |           |           |           |
| Trunk                                |                    | 93        | 92        | 136       | 80        |
| Quarterly (heating)                  |                    | 303       | 252       | 261       | 146       |
| **Non-heating season**               |                    |           |           |           |           |
| Trunk                                |                    | 25        | 13        | 17        | 8         |
| Quarterly (heating)                  |                    | 59        | 42        | 76        | 52        |
| Supplying hot water                  |                    | 164       | 115       | 195       | 65        |
| **Heating season:**                  |                    |           |           |           |           |
| **September-December**               |                    |           |           |           |           |
| Trunk                                |                    | 7         | 12        | 7         | 7         |
| Quarterly (heating)                  |                    | 166       | 232       | 182       | 182       |
| Supplying hot water                  |                    | 84        | 102       | 93        | 93        |
| **Subtotal:**                        |                    |           |           |           |           |
| Trunk                                |                    | 136       | 121       | 166       | 87        |
| Quarterly (heating)                  |                    | 612       | 617       | 606       | 492       |
| Supplying hot water                  |                    | 367       | 294       | 372       | 243       |
| **TOTAL:**                           |                    | **1115**  | **1032**  | **1144**  | **822**   |

5. Findings
Summarizing the experience in determining leaks, we can formulate the following conclusions.
5.1. For the exact location of the leak and its rapid localization, it is preferable to use several methods of detecting outbursts.
5.2. Correlation leak detectors determine the location of an outburst with acceptable accuracy, are used at any time of the year, and determine leaks of minimal intensity. However, the correlation control method has a limitation on the length of the section, because the distance from the sensor setting is not less than 40 m. The practical accuracy of determining the place of ground excavation does not exceed 95%.
5.3. Acoustic leak detectors also accurately determine the location of the impulse, but provided that there are no sources of noise near the surveyed site (highway, etc.), as well as snow cover or ice.
5.4. The thermal imager is most efficiently used when searching for a leak in the spring-autumn period, because the snow cover at the site of a possible outburst masks the leak, and no flow is visible on the thermogram.
5.5. The use of instruments for the search for outbursts and in the performance of maintenance work on pipelines can significantly reduce the loss of chemically treated water.

6. Conclusion
Problems of improving the reliability, safety and efficiency of operation of heat and power equipment are closely related to the tasks of updating the basic production assets and reducing the costs of carrying out repair and restoration activities.

Despite the fact that energy supplying organizations to increase the reliability of heat supply begin to use non-destructive testing methods, the amount of damage to pipelines during the heating period remains significant (Table 2).

As can be seen from the table, a large number of accidents occur on quarterly heating networks.

Table 3 shows the costs of eliminating one accident of a pipeline of different diameter. During calculating the cost, the costs included restoration works (black earth dumping, grass sowing, planting
trees, restoring small architectural forms, etc.), cutting and adding soil during planning, as well as dismantling and paving works.

Table 3. The cost of intra-networks repair for 1 m of the pipeline.

| Diameter, mm | 50    | 80    | 100   | 150   | 200   | 300   | 400    |
|--------------|-------|-------|-------|-------|-------|-------|--------|
| The cost of repair, rub. | 9835.07 | 9859.55 | 10618.92 | 10643.08 | 11320.09 | 11558.60 | 11795.83 |

The significant cost of repair and maintenance, spare parts, installation and emergency restoration work in the context of a shortage of funds dictates the need to develop and implement new maintenance technologies. Under these conditions, the need for scientific research aimed at solving problems related to the improvement of methods and means of assessing the technical condition of heat power equipment significantly increases.

The damageability of urban heating networks is very high and has a pronounced tendency to further increase with the aging of the networks. The main cause of high damage is intense local focal soil corrosion, the reason for which is moisture access to the unprotected surface of the pipe. The fight against high damage should be carried out both in newly built and in existing networks.

Monitoring the state of heating networks should be carried out starting with their acceptance for operation. The control system provides for the creation of assessment methods, instruments and tools to determine the parameters of the technical condition and their compliance with regulatory characteristics, and also allows for timely preventive measures and repairs based on the receipt and processing of data on the state of the elements of the operated heating networks. The data obtained as a result of assessing the state of the structures of the heating networks in operation can serve as a basis for deciding on their repair, as well as reconstruction and modernization.

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