Maintenance of heat stability of the heating system work in a structure

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Abstract. We investigated the reasons of obstruction in elements of heating systems equipped with capacitive heating devices, which leads to an increase in hydraulic resistance, a decrease in the coolant flow rate, a decrease in the average surface temperature of the heater and a decrease in its heat transfer. We studied the decrease in the thermal conductivity of the pipeline walls of the heating system depending on the thickness of the sediment of solid particles on their surface. The analysis of the existing method of flushing heating system is carried out and its shortcomings are revealed. A better method for flushing single-pipe heating system hydraulically is proposed, which involves the following: to ensure effective flushing of capacitive heaters, it is proposed to supply clean water and to remove wastewater from different sides of the heating device. The application of the proposed method allows us to reduce the water consumption for flushing heating system, to reduce the flushing time, to exclude the transfer of solid particles to other elements of the heating system which improves reliability of its operation.

1. Introduction

The heating system must provide reference indoor air temperature. A criterion for the quality of operation of a water heating system is the reliability of maintaining required air temperature in a heated room. During the operation of the system, various malfunctions can occur, for example, insufficient heating of the risers, creation of blockages in the heating risers and supply lines. [1-3]

The main malfunctions of heating systems include: a decrease in indoor air temperature and a violation of the tightness of individual elements of the system. The decrease in air temperature mainly occurs due to a violation of the circulation of water.

One of the reasons of water circulation disorder is obstruction in the heating system. Obstruction occurs due to the ingress of dirt into the heating system (as a result of careless installation), due to defective sediment boxes, and due to deposition of corrosion products on the internal surfaces of pipelines [4-6].

With obstruction of the elements in the heating system, the hydraulic resistance of the system section increases, and this is the reason for the decrease in the coolant flow rate, as a result of which the average surface temperature of the heater decreases, its heat transfer decreases and, as a result, the temperature in the room decreases. [7,8]
2. Research problem statement and theoretical part

Let us consider a decrease in the thermal conductivity of the wall of the heating system pipeline and the temperature of its surface in the case of deposition of solid particles on the walls.

The thermal resistance of the clean (without any sediment) surface of the wall of the heater is determined, m²·°C/W, according to the formula:

\[
R_{\text{wall}} = \frac{\delta_{\text{wall}} \cdot A_h}{\lambda_{\text{wall}} \cdot A_h},
\]

where \(\delta_{\text{wall}}\) – cast iron heater wall thickness, m, \(\delta_{\text{wall}} = 0.004\) m; \(\lambda_{\text{wall}}\) – coefficient of thermal conductivity of the heater wall, W/(m·°C); \(A_h\) – external surface area of the heater, m²; \(A_m\) – internal surface area of the heater, m², for cast-iron heaters according to [9].

\[
\frac{A_h}{A_m} \approx 1.3
\]

The thermal resistance of the wall surface of the heater in the presence of sediment, m²·°C/W, is determined by the formula:

\[
R_{\text{wall}}^{\text{sed}} = \frac{\delta_{\text{wall}} + \delta_{\text{sed}} \cdot A_h}{\lambda_{\text{wall}} + \lambda_{\text{sed}} \cdot A_m},
\]

where \(\delta_{\text{sed}}\) – thickness of sediment, m, determined according to figure 1, obtained during a full-scale experimental study of the elements of the heating system in a residential building; \(\lambda_{\text{sed}}\) – coefficient of thermal conductivity of sediment, W/(m²·°C), \(\lambda_{\text{sed}} = 0.1...7.0\) W/(m²·°C).

Figure 1. The sectional view of the pipe of the heater, during the operation of which the system was not flushed.

The results of calculating the thermal resistance of the heater wall surface with obstruction are presented in figure 2.

The temperature of the outer surface of the heater wall, °C, is determined by the formula:

\[
t_{\text{wall, o}} = t_s - \beta \cdot \mu \cdot q \left[ \frac{\delta_{\text{wall}}}{\lambda_{\text{wall}}} \cdot \frac{2}{1 + \beta} + \frac{\delta_{\text{sed}}}{\lambda_{\text{sed}}} \cdot \left(1 + \chi\right) \cdot \frac{1}{\alpha} \right],
\]

where \(t_s\) – water temperature in the heating system, °C; \(\beta\) – the ratio of the outer diameter of the pipe to the inner one; \(\mu\) – heat distribution coefficient, taken equal to 1; \(q\) – perceived heat load, W/m².
$\alpha$ – heat transfer coefficient from the wall to the heated environment, $W/(m^2\cdot^\circ C)$; $\chi$ – ratio of sediment thickness to pipe diameter.

Figure 2. Change in the value of the thermal resistance of the wall surface of the heater depending on the thickness of the sediment

The results of calculating temperature of the outer surface of the heater wall are presented in figure 3.

Figure 3. Change of the outer surface temperature of the heater wall depending on the thickness of the sediment

In figure 3, it is seen that with the sediment thickness of 4 mm, the surface temperature decreases by 10 $^\circ C$, with the thickness of 7 mm - by 25 $^\circ C$, which once again confirms the need to flush the heating system.

Due to the fact that the water velocity in the columns of the cast-iron heater is small (less than 0.1 m/s), solid particles (dirt, metal oxides, etc.) settle in the lower part of the cast-iron heater. In this case, the live cross-section (cross-section for water passage) of sub-header of a heater decreases and, consequently, the flow rate of the heat carrier decreases (due to an increase in hydraulic resistance), and the layer of solid particles increases the thermal resistance of heat transfer and therefore the temperature of the outer surface of the heater (its lower part) decreases, respectively, the heat transfer of the lower part of the heater decreases due to a decrease in the temperature head, but the entire riser can warm up normally [10].

3. Existing method for flushing the heating system

There is a method of flushing single-pipe heating system with an upper pipe routing. The flushing scheme of the heating system with elevator connection to the heating pipework is presented in [11]. The specified heating system is a single-pipe, with axial closing sections and the upper pipe routing.
Cast-iron heaters of the M140 type are connected to vertical risers using two inlets - supply and reverse. Moreover, both pipe supplies are connected to a cast-iron heater at one side.

Figure 4 shows a fragment of the riser of a single-pipe water heating system with a displaced end section, a three-way valve and the upper pipe routing, the pipe supplies are connected to the heater at one side. It is clearly seen that the largest amount of pollutants in a capacitive heating device is accumulated in the sub-header in sections located closer to the blind plug.

![Figure 4](image)

The efficiency of flushing heating system shown in figure 4 with the usage of the flushing method proposed in [11,12] is extremely low. It is known that cast-iron heaters of the M140 type consist of separate sections that are connected to each other with nipples. Each section has two columns. When the water (heat carrier) moves along the riser 1 at point 2 (three-way valve), the flow should be divided into two parts: one part of the water passes through the supply pipe 3, enters the hood 4 of the heater, then leaves the heater through reverse pipe 12, approaches point 13, connects to a stream of water that passes through the bypass section 14; next, the general flow moves down the riser 1 to the heater located below.

It is necessary to point out that in point 2 the flow of the heat carrier may stay inseparable, in this case all the water discharge, flowing in the heating riser 1 and feeding the supply pipe 3 will be equal, while the water discharge in the water pipe 14 will almost be equal to 0, i.e. all consumed water is going through heater.

The speed of water flow (of heat carrier) in section columns of the heater is not the same. In the columns of the sections 5, 6 and 7 the speed is higher than in the columns of the sections 8, 9 and 10 (figure 4). That is why more solid particles usually settle at the end sections 8, 9 and 10, as they aren’t carried away by the water flow (of heat carrier) because of the low speed.

Thus, in the process of long exploitation solid substances are accumulated at the end sections that reduce the area of live section of the sub-header 11 that diminishes the water consumption (of heat carrier) through end sections 8, 9, 10 of the heater [13-15]. As it was noted above the heat transfer of the heater is reduced both by increase of thermal resistance of the solid particles layer and by decrease of the water consumption (of heat carrier).

In the same way the flushing water is carried in the water heating system and cast iron heater using the known method of flushing of the heating system [11]. Flushing water (tap water used for flushing of system) is fed to the cast-iron heater through supply pipe 3 (figure 2), and is removed from the heater through reverse pipe 12. Both pipes are attached to the same side of the heater (see figure 2 where the pipes are attached to the right part of the heater). In this case, the left part of the sub-header of the heater (the sections 8, 9 and 10 of the cast iron heater) will practically not be flushed of settled solid particles due to the low speed of flushing water.
4. Research results and suggestions

Perennial practice of exploitation of heating systems where cast iron sectional heaters are used, proves that end sections are obstructed deeper and more often [16,17]. To improve flushing of heating system with cast iron heaters the authors of the article present a more effective way of heating system flushing.

Heating system flushing can be carried out hydraulically or hydropneumatically. This article explores only hydraulic way of flushing. In hydraulic flushing high speeds are used (3 … 5 times higher than during heating system operation) by constant tap water flow through heating system or its single unit [18].

Figure 5 shows the scheme of heating system for three-storey house with elevator connected to the heating system. When flushing system is disconnected from the heating system with the help of head gate valves 38 and 39, nozzle and glass are removed from the elevator.

Heating system is cleaned in each water riser apart, beginning with the end riser. Before filling the heating system with tap water the following must be done: blind plug 10 must be screwed out from the cast iron heater (from its sub-header) installed on the second floor, by-pass plug must be screwed in, in which branch pipe 11 with tap 12 are turned in. In tap 12 branch pipe 13 is screwed in. To branch pipe 13 hose 14 is connected, the other end of hose is led down the drainage system.

In the same way branch pipe 16 and 18, tap 17 and hose 19 are installed in by-pass plug of the heater located on the first floor. Branch pipes 21 and 23, tap 22 and hose 24 are installed in the heater on the ground floor.

Then heating riser 1, supply pipe 25 and return line 26 are filled with water by opening gate valves 27, 28 and 29 and taps 6, 7, 30. Taps 31, 32, 33 and 34 must be turned off.

If water appears in air vent 6, it is turned off.

Three-way valve 2 in the process of heater flushing must be adjusted in such a way as to let all water through bypass section 8, i.e. during flushing the tap 2 must shut off the water flow to the cast iron heater 4 by the supply pipe 3, all water consumption must be carried out down the pipe 5 and 8 to the sub-header of the heater.

This constructive solution provides water flow (for the purpose of flushing) in the sub-header of the heater from left to right (figure 4).

As it was mentioned above, numerous solid substances are accumulated in the sub-header of the heater, so that it is the most contaminated. The flow of water for flushing starts in the part of the sub-header where the number of solid substances is less, and they move to the side where their number is more and where the water with more number of solid substances is removed from the sub-header of the heater. This way the transference of solid substances to the other elements of the heating system is eliminated. This enhances the effectiveness of heating system flushing, minimizes the amount of tap water used and reduces the time of flushing.

Removal of wastewater from the heater is carried out through the hose 14 into the sewerage. This part of heating system is flushed until clean water flows from the hose 14, tap 12 is turned off and the flushing of the heater located on the second floor starts. Flushing is carried out when gate valve 28 is open, taps 6, 12, 22, 31, 32 and 33 are closed, gate valve 29 is closed. Flushing is conducted in the same way as of the heater located on the second floor. When the flushing of the heater located on the first floor is finished, tap 17 is closed; all the other heaters connected to the first heating riser are flushed in the same way.

It is worth mentioning that when flushing of the heater located on the ground floor is accomplished, supply pipes 25 and all end riser (storey standpipe) except for the small part of heating riser (from the bottom of the heater located on the ground floor to the return line 26 and part of return line – from the jointing of two neighboring heating risers) are also flushed. The flushing of these two parts is carried out then the gate valve 28 is open, taps 7, 30 are open; taps 6, 31, 32 and 33 are closed. Wastewater is removed through gate valve 35 and hose 36, taps 7 and 30 are open, taps 12, 17, 22 are closed, gate valve 29 is closed.
After flushing of the heating riser 1 taps 7 and 30 are closed and the flushing of the other heating risers starts by successive opening of taps on heating risers. [19-21]

Figure 5. The scheme of flushing single-pipe heating system in a three-storey residential house: 1 – heating riser; 2 - three-way valve (flow dividing point); 3 - supply pipe; 4 – heater; 5 - reverse pipe; 6 – air vent; 7 - tap; 8 - bypass section; 9, 10 – blank heater plug; 11 – branch pipe; 12 – tap; 13 – branch pipe; 14 – hose; 15 - blank heater plug; 16 – branch pipe; 17 – tap; 18 – branch pipe; 19 – hose; 20 – blank heater plug; 21 – branch pipe; 22 – tap; 23 – branch pipe; 24 – hose; 25 – supply pipe; 26 – return line; 27, 28, 29 – gate valve; 30, 31, 32, 33, 34, 35 – taps; 36 – hose; 37, 38, 39 – gate valve.

5. Conclusion
The article analyses reduction of heat conduction of the pipeline surface of the heating system depending on thickness layer of particulate matter on its walls. It was found out that when the thickness of sedimentation is 7 mm the temperature of pipeline surface is almost 25 °C lower.

The main drawbacks of the existing methodology of heating system flushing are found out. They are connected with the fact that the supply and disposal of flushing water are carried out from the same side of the heater. The flushing of sub-header is not performed, that causes gradual decrease in heat transfer of the device by decreasing the flow of coolant and increasing thermal resistance of the lower part of the heater.

The presented scheme of flushing provides effective flushing of the heaters by supplying and disposal of flushing water from the different sides of the heater. The application of the offered scheme makes it possible:

- to reduce consumption of water for heating system flushing;
- to reduce the time of heating system flushing;
- to eliminate transference of the particulate matter to the other elements of heating system, that improves the effectiveness of its operation.
The described way of flushing can be applied in the heating systems of buildings of any height, its use is conditioned by design features of heaters, allowing to attach drain hose from the side of heater, opposite to the flushing water supply.

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