Research of equipment for pulsed heating supply

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Abstract. Proposed scheme of individual heating unit (IHU) contains a mixing device based on energy-efficient two-flow membrane pump operating in pulse mode at available head of the heating network. The problem was solved of finding the optimal regimes of membrane pump work, which provided qualitative and economical efficacy of heating devices. Experimental graphs illustrate the pressure changes in the working chambers of the pump equipped with a pulse heating medium flow distributor. It is shown that implementation of the membrane pump in the IHU circuit allows distributing temperature more evenly throughout the heating devices surface due to pulsating mode of the heating media movement.

Key words: individual heating unit, mixing device, two-flow membrane pump, pulse flow distributor, heating medium temperature distribution.

1. Introduction

To date, most of the buildings in urban settlements are connected to district heat networks. In such cases, heating medium is mixed mainly by means of mixing devices based on the water-jet elevators. Water-jet elevators use the available head in the heat network and do not require additional drive, they are quite reliable and easy to operate, but they are highly dependent on the available head in the heat network. Head required for normal operation of the water jet elevator is 20-30 m [1]. If this condition is not met, operation of the heating unit based on a water jet elevator is partially or completely disturbed [2]. This phenomenon became especially frequent with expansion of the effective range of heat networks which, in some Russian cities, exceeds 9 kilometers. It is very difficult to provide a proper hydraulic mode in these conditions, therefore new buildings are connected to heating networks using an independent scheme, through a heat exchanger. It is mainly not possible to connect old buildings using an independent connection scheme for heating and ventilation systems of the building because of multiple inputs and old pipeline circuits in basements. Energy surveys performed in 2012 in the budget sector revealed main drawbacks of traditional dependent schemes for buildings connection to heating networks and main of them is overheating of returned network water at the change of available head in the heating network and reduction of heating efficiency. Technical solutions were proposed consisting in installation of additional monoblock pumps of Wilo, Grundfos type, etc. in the feed-up line. In some cases, in places where energy saving potential was revealed in buildings, weather regulators were installed in the heating medium supply pipe of the building individual heating units (IHU). However, work of the latter has a significant impact on hydraulic equipment of neighboring buildings [3]. There is an opinion among experts that mass use of weather
regulators can completely disturb hydraulic mode of a heating system [4]. On the other hand, use of additional mixing pumps and weather regulation in the IHU, especially in the autumn-spring period, reduces efficiency of heating devices. Adding of such a membrane pump into the IHU circuit provides high-quality mixing of heating medium, which will allow more evenly distributing temperature throughout the heating device surface due to the pulsating mode of the heating medium movement [5,6,7]. In this regard, it is very important and practical to search for constructive solutions that could solve these problems with minimal energy consumption.

2. Methods and equipment

This paper describes a scheme of an individual heating unit with energy-efficient mixing device based on special two-flow membrane pump operating at the available head in the heating system. Adding of such a membrane pump into the IHU circuit provides high-quality mixing of heating medium which will distribute temperature more evenly over the surface of the heating devices due to the pulsating mode of the heating media movement [8, 9, 10].

Figure 1 shows a diagram of individual calorific unit including membrane pump which comprises: feed 1 and reverse 2 pipe-lines, left 3 and right 4 sections of membrane pump; pulse flow distributor 5 with 6 (right) and 7 (left) valves; right 8 and left 9 stems of pulse flow distributor; cam of pulse flow distributor 10 connected to electric drive 11, left 12 and right 13 working chambers of the membrane pump; left 14 and right 15 nozzles of the membrane pump; stem 16; mechanism for switching of dart valve 17; left 18 and right 19 dart valves; heating devices of the right 20 and left 21 sections; pumping chambers 22 and 24; discharge recirculation check valves of right 23 and left 25 sections; discharge recirculation check valves 26, 27 and suction check valves 28, 29.

Individual heating unit with membrane pump works as follows. Suppose that the left dart valve 18 is closed, and the right dart valve 19 is open, cam of the pulse flow distributor 10 is in position I (figure 2), at that the right valve of the pulse flow distributor 6 is open and the left valve of the pulse flow distributor 7 is closed. When the heating medium is fed into the supply pipeline 1 it begins moving along the following circuit: supply pipeline 1, pulse flow distributor 5, supply nozzle of the right section of the membrane pump 15, right working chamber 13 of the right section 4 of the membrane pump, right dart valve 19, heating device of the right section 20 and further into the return pipeline 2. When the steady-state mode of the heating medium is reached, the electric drive 11 turns on and begins to rotate the cam 10 and the left rod of the pulse flow distributor 9 jumps into the slot of the cam 10, this will lead to subsequent sharp closing of the left valve 7, and the right rod 8 will ride over the cam and smoothly open the right valve 6. If to rotate the cam further, the left valve 7 will be closed, and the right valve 6 will open for some time, and then will be kept open until position II of the cam. When the right valve 6 reaches fully open position, the stem 16 will be in a left extreme position, the switching mechanism of the dart valves 17 will operate that will cause sharp switching of the dart valves: the right dart valve 19 will close, and the left dart valve 18 will open. When the right dart valve 19 is abruptly closed, a water hammer will occur and further reverse wave appeared will create a pressure pulse that will reach the right working chamber 13 of the right section 4 and will give acceleration at the beginning of the movement of the rod 16. Further movement of the rod will occur under the influence of the pressure difference between the direct and reverse pipeline 2. The membrane of the right section of the membrane pump 4 will move from left to right, dragging the rod 16, and heating medium will be fed from the pump chamber 22, through the discharge check valve of the right section 23 to the heating device of the right section 20 and further into the return pipeline 2. When the heating media passes through the heating device, secondary heat of the heating medium is transferred of the right section 20 and accumulated primary heat of the heating media is transferred to ambient air. At this time, heating medium from the left working chamber 12 of the left section of the membrane pump 3, through the discharge recirculation check valve of the left section 26 and suction check valve of the left section 28, will flow through the open dart valve 18 and the heating device of the left section 21 into the left pump chamber 24, under the action of the pressure difference in them. When the heating medium passes through the heating device of the left section 21, heat energy is accumulated and transferred.
When cam of the pulse flow distributor 10 is switched to position II, valves of the pulse flow distributor will be switched and the process will occur in the right section that similar to that in left.

Reliable operation of the device is provided at frequency of heating medium flow interruption from 0.4 to 0.8 Hz. At that, heating medium flow rate is reduced to 30 % at increase in the flow interruption frequency. Ratio of primary and secondary heating medium mixing is 2.

The scheme is implemented at the Department of heat and power systems of FSBEI of Higher Education “Mordovia State University named after N.P. Ogarev” in the form of IHU prototype with consumption of 3 t/h. The IHU prototype includes a pulse flow distributor of heating medium with the electric drive (Figure 3) and a two-flow membrane pump (Figure 4).
3. Results and discussion
The main task of testing IHU with a two-flow membrane pump is defining the following data: dependence of pressure in the working and pumping chambers on flow interruption frequency; dependence of flow rate on flow interruption frequency; temperature distribution pattern throughout the surface of heating devices. Graphs of pressure in the chambers at two frequencies - 0.4 and 0.8 Hz - are shown in Figures 5 and 6.
It can be seen from the graphs that when the flow interruption frequency changes from 0.4 Hz to 0.8 Hz, pressure amplitude in the working and pumping chambers almost does not change.

Hydraulic characteristics of the IHU prototype depends on frequency of the pulse heating medium flow distributor (figure 7). As can be seen in this Figure, a significant change in the flow rate is observed in the frequency band from 0.5 to 0.6 Hz. At frequencies less than 0.5 Hz and more than 0.6 Hz, heating medium flow rate varies slightly; this is due to the design features of the pump piping.

![Figure 7. Flow rate of the membrane pump versus frequency.](image)

The IHU prototype was loaded with BM RBS-500 bimetallic radiators. Temperature distribution throughout the surface of one of the heating devices, at static mode and at pulse mode with flow interruption frequency of 0.45 Hz, is shown in figure 8. As can be seen from this Figure, the pulsating flow of the heating medium allows increasing about 30% the convective heat exchange in the working units with low temperatures (43-47.6°C) on the radiator surface.

![Figure 8. Temperature distribution diagrams in the working units of the sectional bimetallic radiator](image)
4. Conclusions

1. The practice of IHU operation makes it possible to conclude that use of additional mixing pumps and weather regulation, especially in the autumn-spring period, reduces efficiency of heating devices. In this regard, it is very important and practical to search for design solutions that could solve these problems with minimal energy consumption. One of the possible solutions is addition to the IHU scheme a pump-mixing device based on a special two-flow membrane pump operating at the available head in the heating network. Adding of such a membrane pump into the IHU circuit provides high-quality mixing of heating medium which will distribute temperature more evenly throughout the surface of the heating devices due to the pulsating mode of the heating medium movement.

2. As a result of the IHU testing with energy-independent pump-mixing device based on a special two-flow membrane pump operating at available head of the heating system, it was found out that, when flow interruption frequency changes from 0.4 Hz to 0.8 Hz, pressure amplitude in the working and pumping chambers practically does not change.

3. Hydraulic characteristics of the IHU prototype depends on frequency of the heating medium pulse flow distributor. At the same time, a significant change in the flow rate is observed in the frequency band from 0.5 to 0.6 Hz. At frequencies less than 0.5 Hz and more than 0.6 Hz, heating medium flow rate varies slightly, this is due to the design features of the pump piping.

4. Temperature distribution throughout the surface of one of the BM RBS-500 heating devices at static mode and at pulse mode at flow interruption frequency of 0.45 Hz shows that pulsating flow of the heating medium increases the convective heat exchange by 30% in working units with low temperatures.

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