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Thermohydraulic Conditions of Heating Networks in Tyumen

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Abstract

The paper, which aims at improving energy efficiency of the district heating systems, gives a brief overview of the study on heating networks. The major challenges of heat supply systems in Russian Federation have been pointed out, and an analysis of the actual network parameters has been done based on heat duty consumption in the heating season of 2012-2013; Here, significant excursions have been revealed in the return pipeline actual temperature and heat carrier flow from the rated parameters in thermal chambers of the main pipeline taken in different zones of the heating network. Based on the analysis done, the authors have concluded that unbalances between the heat carrier flow and return pipeline temperature are interrelated and the thermohydraulic conditions at CHPP-2 are "unfavorable". The paper presents a piezometric graph of the heating network from Tyumen CHPP-2 to the final thermal chamber under study. The graph has revealed unbalances in the heating network performance.

Keywords: Energy efficiency of the heat supply system, rated and actual flow of the heat carrier, rated and actual temperature of the heat carrier, pressure of the heat carrier in the heating network, piezometric graph.

INTRODUCTION

The study has resulted in revealing the increased pressure in the return heat pipeline as compared to the flow one; this indicates the effect of the "overturning" of hydraulic networks which affects the thermal and hydraulic conditions of neighboring consumers and thus, the probability of boiling in the heating network increases when the heat carrier pressure is insufficient; this, in turn, can lead to structural failure of the heat pipeline.

Effective (rational) use of energy resources has been challenging since heat supply systems appeared. It is the desire to improve energy efficiency of heat supply that led to district heat supply based on combined generation of electricity and heat. Regulation of heat duties is a complicated process involving implementation of a number of challenges that are closely interrelated, i.e. at least three parameters of the heating network are subject to regulation. At present, heat supply lacks in the reliable and economically justified way of its effective use, thus the study proves to be relevant. Energy efficiency is urgent for most regions of Russia including Tyumen, taking into account the large territory of Russia with a large number of CHPPs where up to 70% of the produced heat is not transferred to consumers, since one half of it is lost in the heating plants, the other half - in buildings and facilities.

Russian heat supply systems face the following challenges:

- lack of reliable data on the actual state of heat supply systems;
- lack of promising master plans, municipal energy plans and updated heat supply schemes in most settlements;
- significant excess capacity of heat supply sources and optimistic estimates of consumers' heat duties;
- high level of losses in heating networks due to wear of heating networks and growth of networks in need of urgent replacement;
- maladjustment of heat supply systems (high losses from overheating up to 30-50%) [1, 2, 10].

The paper presents the results of studies on the main heating networks at CHPP-2 in Tyumen. Thus, an attempt has been made to identify the main factors that affect energy efficiency decrease in district heating systems [1, 11].

THE RESULTS OF THE SERIES OF EXPERIMENTS AND THEIR ANALYSIS

The analysis of the existing heat supply system is based on revealing temperature and flow excursions. These parameters are the main criteria for heat supply system efficiency. It is also necessary to maintain set pressure of the heat carrier in the flow and return pipes. This allows the heat carrier to circulate in the heat supply system of the city. Thus, a reliable hydraulic condition is the most important factor for heat carriers' supply [7, 9]. Thus, it has been decided to study the actual parameters of the network in terms of heat duty consumption in the heating season of 2012-2013.

Fig. 1 shows the location diagram of thermal chambers in relation to the heat supply source. The diagram shows that two main lines pass from the heat supply source of CHPP-2; one is directed towards the thermal chamber 9k1A, the second one - towards the pavilion 9P3.

Looping back of the network is made through the thermal chamber 4k27 which, in turn, is connected to the thermal chamber 4K26A. Then heat enters the thermal chamber 4K11, which is a part of thermohydraulic looping back, through the thermal chamber 9K7 and the pavilion 4P7.

Several thermal chambers located in different zones of the heating network have been selected to study the district heating system. Availability of a remote data acquisition system is urgent to collect data on heat carrier performance. They are obtained using the automated system of commercial heat energy metering (ASCHEM) which was installed at the boundary point of main and distribution heating networks [2]. The system implemented in Tyumen in 2011 aims at monitoring the main parameters of the heat supply system. It includes the main units to measure pressure, temperature and flow of the heat carrier.

The three-month study has shown that location of thermal chambers depends on the actual and rated flow, on the actual and rated temperatures of the flow and return heat pipes [3].

These dependencies resulted in a location curve of thermal chambers dependent upon the actual and rated temperatures of the flow and return heat pipes in the heating season of 2012-2013, in accordance with the temperature chart to control heating networks, in relation to the average outside air temperature in November 2012. The rated temperature was taken from the temperature chart of heating networks taking into account the average actual outside air temperature in November 2012. The curves are shown in Fig. 2.

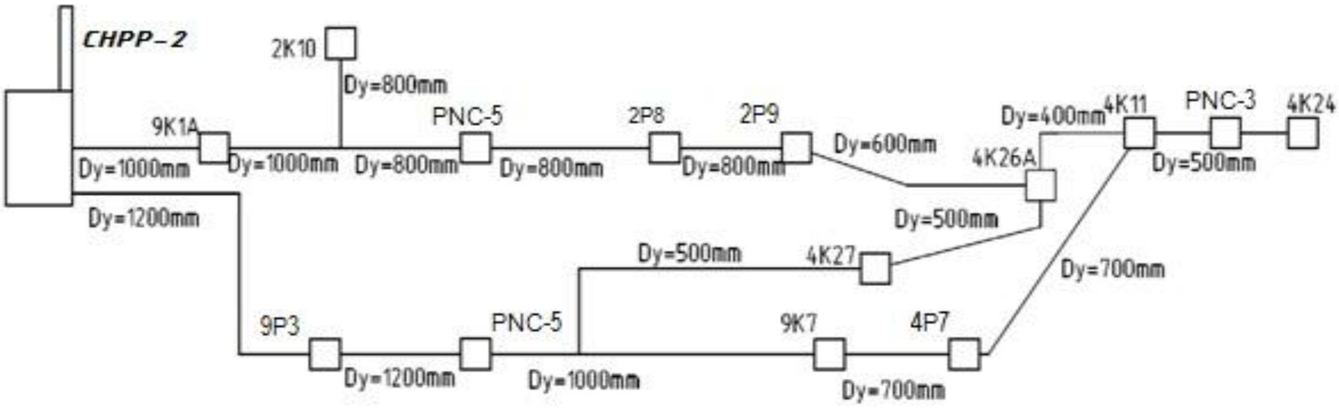

Figure 1. Location diagram of thermal chambers in relation to the heat supply source (compiled by the authors)

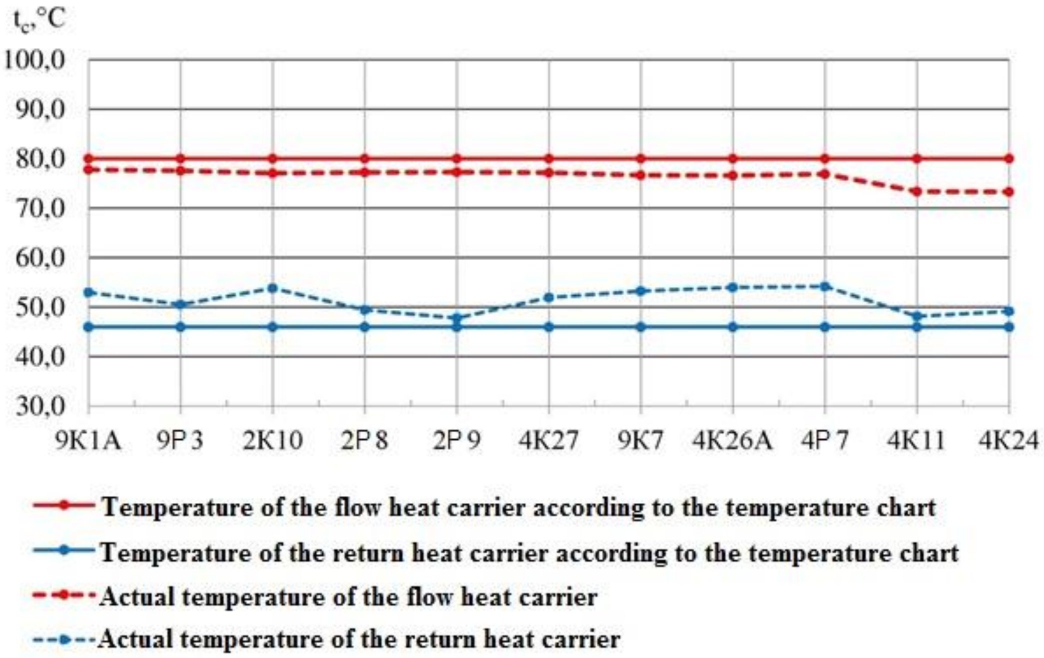

Figure 2. Location curves of the thermal chambers dependent upon the actual and rated temperatures of the flow and return heat pipes in the heating season of 2012-2013, in accordance with the temperature chart to control heating networks, in relation to the average outside air temperature in November 2012 (plotted by the authors).

The curve shows that temperature excursions in the flow heat pipe are observed in all branches from the main pipe of the heating network and range from 2.8% to 8.4%. The greatest excursion is observed in the branches of the main thermal chambers - 4K11 and 4K24. Here, excursions are related to thermal losses along the length of the heating network, and the end users suffer from the low rate of heat carrier flow which, in turn, is physically dependent on pressure losses, heat pipe diameters and the available head between flow and return pipes. Excursions of the return heat carrier range from 4.7% to 17.8%, with a norm of ± 5% [4]. The greatest excursions are observed in the branches of 4K26A and 4P7. Such an excursion is possible due to incorrect setting of the automated control and management system for individual and central heating points, which operate according to the weather-dependent principle. Due to fact that not any significant temperature excursions in the flow pipe have been revealed, except end users.

Heat carrier rate is one of the most essential parameters of the heat supply system. This parameter characterizes both the thermal condition of the heat pipe and hydraulic condition of the heat distribution system. Thus, the location curve of the thermal chambers dependent on the actual and rated flow of the heat carrier has been plotted (Fig. 3).

The curve shown in Fig. 3 indicates significant excursions in the actual heat carrier flow rate. Moreover, this excursion is observed both in decrease and excess of the heat carrier flow. In excess of the flow, the excursions have been recorded in the range from 3.7% to 49.2%; in here, the greatest excursion has been recorded in the thermal chamber 9K7- 49.2%. The excursion has also been recorded in decrease of the heat carrier flow. Thus, the excursion has been 18% in the pavilion 2P8, and 31.6% - in the thermal chamber 4K11.

In here, there have not been any significant excursions from the rated heat parameters in the difference of flows between the flow and return heat pipes. Therefore, there have not been any emergencies. The study on distribution of the heat carrier in Tyumen CHPP-2 in November showed an unstable hydraulic condition and temperature excursions both in the flow and return heat pipes of the heating network.

In January 2013, in the middle of the winter period of heat distribution and consumption, a similar assessment of the hydraulic conditions of the heating network was carried out. In order to confirm the theory that the transition period from winter to summer is the most unstable in hydraulic regulation, it was decided to study the parameters of heat consumption in March 2013.

The curves, similar to those for November 2012, were plotted for these months. The results of the most significant excursions are given in tables 1 and 2.

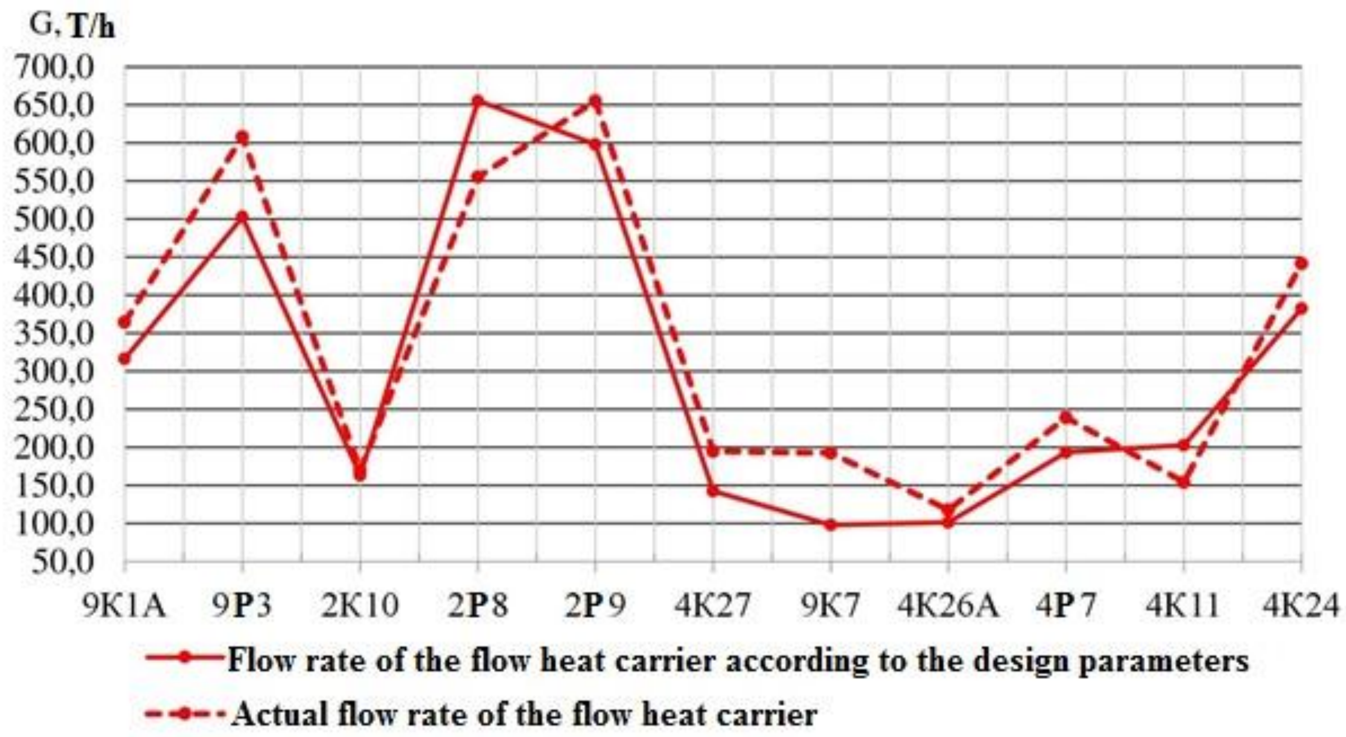

Figure 3. Location curve of the thermal chambers dependent upon the actual rated flow of the heating pipe in the heating season of 2012-2013, in November 2012 (plotted by the authors)

Table 1. Comparison of the actual and rated parameters of thermal chambers over January, 2013

Chamber	Temperature excursion of the flow pipeline from the rated parameter, %	Temperature excursion of the return pipeline from the rated parameter, %	Flow rate excursion from the rated parameter, %	Reasons of excursions
4K24	5			It is the end user. The situation worsens because of the low flow rate of the heat carrier.
4K26		23.6		Probably, the automated system for monitoring and controlling the individual and central heat points is incorrectly adjusted by the heat consumer, since no significant temperature excursions in the flow pipeline have been identified.
4P7		25.8		
4K27			25.5	Temperature increase in the return pipeline

(compiled by the authors)

Table 2. Comparison of the actual and rated parameters of thermal chambers over March, 2013

Chamber	Temperature excursion of the flow pipeline from the rated parameter, %	Temperature excursion of the return pipeline from the rated parameter, %	Flow rate excursion from the rated parameter, %	Reasons of excursions
4K11		19.6		Wrong adjustment of the system of automatic control and diagnostics of engineering equipment located immediately in the place of heat consumption.
4K26a		15.9		
4P7		15.9		
4K27			25.5	Temperature increase in the return pipeline
4K26a			21.4	

(compiled by the authors)

Summarizing the results of the study on heating network section running efficiency at Tyumen CHPP-2 in the heating season of 2012-2013, it is necessary to underline that the following excursions from the stable thermal and hydraulic conditions have been identified:

•in the temperature of the flow heat pipe at the end main thermal chambers;

•in the temperature of the return heat pipe for the whole of the studied main thermal chambers except 2P8 and 2P9;

•in the flow rate of the heat carrier in relation to the design parameter for the whole of the studied main thermal chambers, except 2K10 and 2P9.

Significant excursions in the flow and temperature of the return heat pipe presuppose unfavorable thermal and hydraulic conditions; besides, irrelevant flow of the heat carrier is largely due to temperature increase in the return heat pipe, since this excursion results in the increase of heat carrier flow rate. Otherwise, the consumer decreases the heat carrier parameters and thus, does not warm the premises; this, in turn, affects comfortable stay of people there.

Stability of the hydraulic conditions of heat supply depends on pressure distribution throughout the main and distribution networks. If exact locations to change pressure in the heating network are found, the possibility to improve efficiency of pressure distribution exists. Therefore, it is needed to study the existing available pressure in the main heating network by plotting a piezometric graph with reference to the elevation marks of the land (Fig. 4) [5].

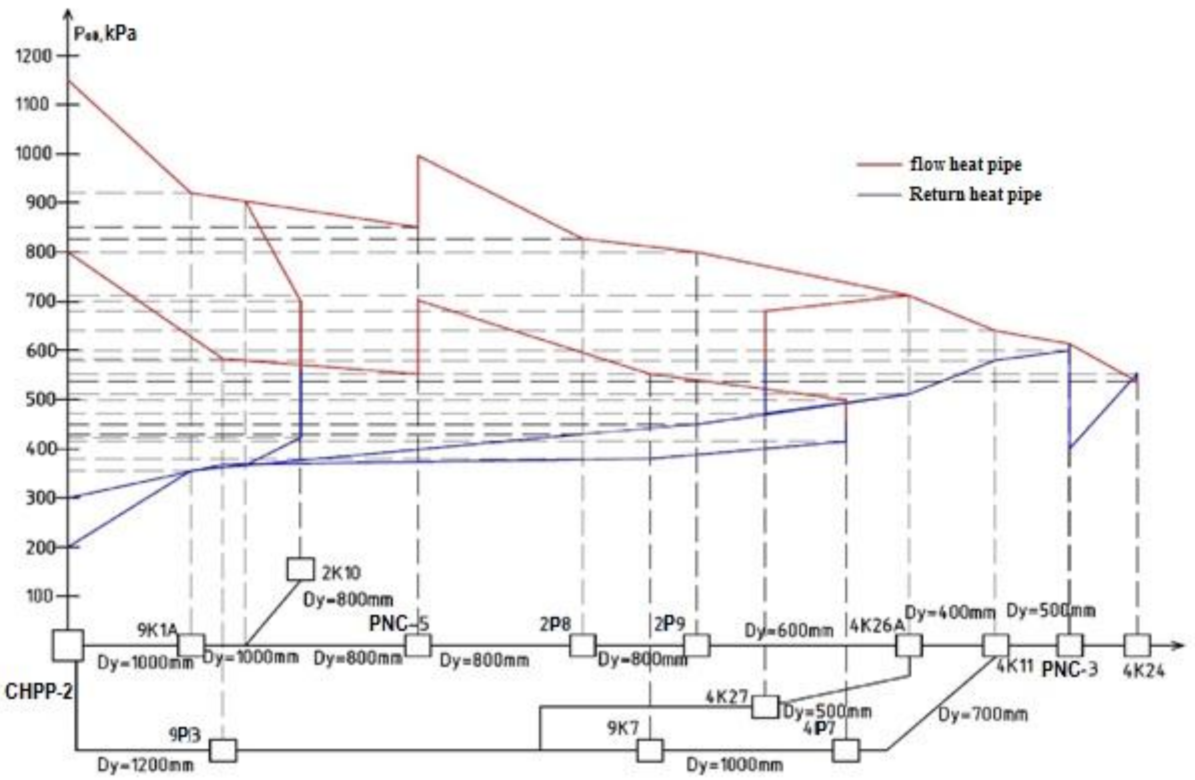

Figure 4. Piezometric graph from Tyumen CHPP-2 to the thermal chamber 4K24 (plotted by the authors)

The figure shows pressure distribution in the main heating network section from Tyumen CHPP-2 to the thermal chamber 4K24 in the heating season of 2012-2013. The graph illustrates both the main and supplementary heat pipes. The main pipe suffers more from drops and duties, but the diameter of the main pipe is smaller than that of the supplementary one. This indicates that the supplementary heat pipe is needed for the promising development areas of Tyumen, and the majority of consumers will use it according to the city development plan [6, 8]. The graph helps determine a significant pressure drop at the initial points which does not have a beneficial effect on the hydraulic condition of the distribution heating networks, and the probability of hydraulic unbalance of the network increases. The pressure drop is quite balanced in the middle of the main heating network.

CONCLUSION

In particular, the thermal condition has a beneficial effect on the distribution heating networks from the connection point to the thermal pavilion 2P9. Pressure increases in the return pipeline of the main heat pipe beyond the pavilion 2P9. As a result, pressure in the thermal chamber 4K24 is higher in the return heat pipe than in the flow one; this indicates the effect of the "overturning" of hydraulic networks which affects the thermal and hydraulic conditions of neighboring consumers and thus, the probability of boiling in the heating network increases when the heat carrier pressure is insufficient; this, in turn, can lead to structural failure of the heat pipeline.

The piezometric graph has indicated the fact of unbalance of the heating network in which hydraulic stability of the system tends to wear with every new heating season.

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