Improvement of decentralized heat supply systems

E Yu Anisimova

Department of Town Planning, Engineering Networks and Systems, South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, Russia

E-mail: anisimova.eyu@mail.ru

Abstract. This article deals with the description results of the decentralized heat supply system operation using a thermohydraulic separator. It presents the essential drawbacks of the most widespread centralized heat supply system. It explains the essence and the operating principle of the thermohydraulic separator, as well as the advantages of its use. It presents the results of computer simulation, made in the SolidWorks program, of the typical operating modes of the hydraulic contour of the decentralized heat supply system when the flows are separated by the thermohydraulic separator. The obtained data are analyzed. The author gives recommendations on choosing a thermohydraulic separator, taking into account its operating features, which depend on the overall dimensions of the separator.

1. Introduction

Currently, centralized heat supply (CHS) is predominantly used in Russia. It is justified by the economical fuel consumption and a relatively low air pollution level. However, in recent years, the non-observance of temperature charts and required available heads at the consumers, major losses of heat and significant leakages of the heat carrier in networks have been observed in the CHS systems. These problems lead to a decrease in the heat supply efficiency and reliability, an increase in the energy resource tariffs at a decrease in the quality of the provided services.

To date, a large number of works deal with the problem of increasing the energy efficiency and reliability of block heat supply systems. The authors propose solutions to improve the quality and energy efficiency of the block heat supply systems both in case of CHS [1-3] and decentralized heat supply (DCHS) [4-6]. DCHS systems are characterized by a high quality of block heat supply at lower economic costs. A modern heat supply system should be simple, reliable, energy efficient and economical. An analysis of the technical literature [3,7-14] has shown that these requirements are met by the heat supply systems using a thermohydraulic separator (THS).

2. Main part

A thermohydraulic separator (THS) is a device for the hydraulic separation of heat carrier flows between the primary contour (often boiler) and the secondary contour (consumer contour) [7]. The THS is widely used in DCHS systems [8-11], and also, according to [3,12], in CHS systems. In addition, the use of THS schemes in boiler houses and individual heating plants (IHP) does not violate the requirements of the normative literature [15-20]. When installing the THS, a favorable operating mode for the boiler is created in the DCHS scheme, the probability of the destruction of its heat exchanger due to temperature stresses and hydraulic shocks is reduced. At the same time, the THS is also a gravitation filter for large suspended particles (sludge), it removes non-condensable gases (air).
through an automatic air vent installed in the upper part of the THS. All the methods and practical recommendations for selecting and calculating the THS [12,13] are rather approximate and simplified. They are based on obtaining the slowest vertical movement in the THS, since it provides the above advantages. It is believed that the vertical velocity in the THS body should not be more than 0.1 m/s. Thus, the THS calculation is reduced to determining its minimum diameter. However, no one has an issue with: estimating the temperature drop in the supply pipeline due to the convection in the THS body, as a result of which the heat carrier flows are mixed, which leads to a decrease in the design temperature of the heat carrier at the THS outlet. Therefore, this paper considers in detail the processes of the distribution of velocities, pressures and temperatures of the heat carrier in the THS body and analyzes the question of the THS application and influence on the operation of the boiler flow diagram. Simulation of the hydraulic contour operation processes made in the SolidWorks program allows us to obtain the necessary data on the main parameters of the heat carrier with a high accuracy.

Let us consider an autonomous DC HS system based on an automated block-modular boiler-house using the THS. This paper studies the design of the THS with a horizontal collector with four different heat consumers: heating system (HS), ventilation system (VS), hot water supply system (HWS) and auxiliaries of the boiler house (ABH). The THS chosen for the study has a design (base) diameter of 325 mm, which corresponds to our specific conditions of the selection procedures [7,13,14].

Thus, four operating modes of the hydraulic contour were simulated for the THS with the body diameter of 325 mm:

- **mode 1** - "design" mode, when the heat load on all the consumers (HS, VS, HWS and ABH) will be maximum, therefore, the flow rates in all the consumer contours will be maximum. It has been assumed that in this mode all the ball valves will be fully open;

- **mode 2** - "night" mode, when the heat load will be maximum on the HS and ABN and lower than the design one on the HWS system (HWS circulation), the VS contour will be completely disconnected. It has been assumed that in this mode the ball valves on the HS and ABH contours be fully open; the ball valve on the HWS system contour will be partially open; the ball valve on the VS contour will be completely closed;

- **mode 3** - "transient" (spring-autumn) mode, when the heat load on the HS, VS and ABH will be lower than the design one, the load on the HWS system will be maximum. It has been assumed that in this mode the ball valves on the HS, VS and ABH contours are partially open, and the ball valve on the HWS system contour will be fully open;

- **mode 4** - "summer" mode, when the HS, VS and ABH contours will be completely disconnected, the load on the HWS system will be lower than the design one - summer. It has been assumed that in this mode the ball valves on the HS, VS and ABH contours are completely closed, the ball valve on the HWS system contour will be partially open.

As a result, we obtained a chronogram of velocities, pressures and temperatures of heat carriers at the section of the boiler flow diagram for the THS with the diameters of 325 mm for all the four modes.

For example, the chronogram of the heat carrier velocities at the section of the boiler flow diagram for an assembly with THS-325 at the design operating mode is shown in figure 1.

The following symbols are used in figure 1: V1.1, V2.1 – heat carrier velocity at the outlet and inlet, respectively, from the boiler contour and is 1.36 m/s; V1.2, V2.2 - heat carrier velocity at the inlet and outlet, respectively, from the consumer contour and is 1.36 m/s; V - vertical velocity in the THS, is 0.06 m/s. We can draw the following conclusions from figure 1: the heat carrier velocity in the nozzles at the THS inlet and outlet obtained as a result of the simulation does not differ from the design one, which confirms the adequacy of the model; the vertical velocity of the heat carrier movement in the THS turned out to be below 0.1 m/s, which complies with the recommendations for selecting the THS body diameter. The velocity of the heat carrier movement is reduced in the THS between the inlet and outlet nozzles as a result of a sudden expansion of the flow.
Figure 1. Chronogram of the heat carrier velocities at the section of the boiler flow diagram for an assembly with THS-325 at the design operating mode.

A chronogram of pressures at the section of the boiler flow diagram for an assembly with THS-325 at the design operating mode is shown in figure 2. The following symbols are used in figure 2: P1.1, P2.1 – pressure at the outlet and inlet, respectively, from the boiler contour and is P1.1 = 126.5 kPa, P2.1 = 132.5 kPa; P1.2, P2.2 – pressure at the inlet and outlet respectively from the consumer contour and is P1.2 = 125.5 kPa, P2.2 = 133.5 kPa; ΔP – differential pressure in the THS, is 9 kPa. The following conclusions can be drawn from figure 2: the heat carrier pressure in the THS is different in height as a result of the influence of gravitational forces; ignoring the gravitational forces, the pressure will be the same throughout the THS height (to confirm it, a similar pressure chronogram was built ignoring the gravitational forces); the actual differential pressure corresponds to the static pressure of the liquid column throughout the THS height. The literature often uses the assumption that the differential pressure in the THS is zero. However, we recommend to take into account this factor.

Figure 2. Chronogram of pressures at the section of the boiler flow diagram for an assembly with THS-325 at the design operating mode.
A chronogram of the heat carrier temperatures at the section of the boiler flow diagram for an assembly with THS-325 at the design operating mode is shown in figure 3.

The following symbols are used in figure 3: 

- T1.1, T2.1 – temperature at the outlet and inlet from the boiler contour, respectively, and is T1.1 = 95 °C, T2.1 = 72.5 °C; 
- T1.2, T2.2 - temperature at the outlet and inlet respectively, from the consumer contour and is T1.2 = 92.5 °C, T2.2 = 70 °C; 
- ΔT - deviation from the required parameter 2.5 °C. 

According to the chronogram in figure 3, the following conclusions can be drawn:

As a result of a convection mixing of heat carrier flows inside the THS, there is a deviation from the design temperature in the supply line (ΔT = 95 - 92.5 = 2.5 °C).

There is an increase in the temperature in the return line at the inlet to the boiler contour (70 °C → 72.5 °C). The inhomogeneity of the temperature distribution is observed inside the THS.

Similar chronograms were built for the model with THS-325 for the "night", "transient" and "summer" operating modes of the hydraulic contour.

3. Conclusion

Thus, based on the results of the simulation and the analysis of the obtained data on the THS operation in the boiler flow diagram in various hydraulic modes of the consumer contours, it was established that:

- the installation of the THS in the boiler flow diagram actually allows us to optimize the operation of the DCHS system with several different heat energy consumption systems. The quantitative regulation of the heat load is generally used in such systems, which in turn leads to variable hydraulic conditions in the heat supply system. The optimization is due to the creation of constant hydraulic conditions in the boiler contour, regardless of the flow rate and pressure drops in the heat energy consumer contours;
- there is a complete pressure drop in the THS between the supply and return lines, except for the static component of the liquid column pressure (gravity pressure);
• the use of the THS with the overall dimensions according to the standard selection procedures [7,13,14], allows us to efficiently separate the contours, as well as use the THS as a gravitation filter for sludge sinking and remove the resulting accumulations of gas bubbles from the heat carrier by reducing the heat carrier velocity. However, due to the convection of the heat carrier in the THS in the design mode, the heat carrier temperature in the supply line in the consumer contour decreases (by about 2-3 °C).

4. Findings

In this paper, we analyze the operation of the THS in the DCHS system based on a block-modular automated boiler house with various heat energy consumers.

As a result of studying typical operating modes of the hydraulic THS contour in the SolidWorks program, it was revealed that the introduction of the THS into boiler flow diagrams actually allows us to ensure optimal hydraulic conditions of the boiler contour, thus, increasing the service life of boilers, and also to increase the performance and quality of the DCHS system. The THS has a rather simple design and low cost as compared to heat exchangers.

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