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Analysis of the design features of transformer heating elements in electrical complexes of decentralized heat supply

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Abstract. *The paper analyzes the design features of transformer heating elements used in electrical complexes of decentralized heat supply. Particular attention is paid to the dependence of the efficiency and reliability of the element on operating conditions, such as the properties of the coolant and the possibility of scale formation. Single-phase and three-phase designs with a sealed secondary winding are considered, as well as heating elements with a three-phase spatial magnetic circuit and a central tube for fluid circulation. It is shown that the proposed design solutions provide an increased heat transfer coefficient, uniform distribution of the thermal load and a high level of electrical safety. The results obtained indicate the feasibility of using such heating elements in decentralized heat supply systems to increase the efficiency and reliability of heat exchange devices.*

Key words: *electrotechnical complex, heating, heat supply, electric heating method, heating element.*

Analysis of previous studies. A feature of the transformer-type heating element, which is part of the electric complex of decentralized heat supply, is that its design directly depends on the operating conditions. In particular, to increase the efficiency and reliability of the heater in the case of heating liquid media, it is necessary to provide a sufficiently large heat exchange area, which takes into account the possibility of scale formation and other deposits on the heating surface. This allows maintaining the optimal thermal regime and preventing overheating of the heater surface. In addition, an important parameter is the specific surface power, i.e. power per unit of heat exchange area. For devices intended for heating water, it should not exceed 10 W/cm², since exceeding this indicator can lead to intensive scale formation and a decrease in the durability of the element [1].

The purpose of the study is to analyze the design features of the transformer heating element as part of the electric complex of decentralized heat supply, to determine the factors that affect its efficiency, reliability and operational characteristics.

Presenting main material. Among the numerous designs of transformer electric heating elements considered in works [2–4], the most promising are single-phase heaters with a power of up to 5 kW and three-phase transformer heating elements with a secondary winding made in the form of a hermetic housing made of sheet conductive

material [5]. The use of a hermetic housing provides reliable insulation of the secondary winding from the coolant and prevents the formation of corrosion, which significantly increases the service life of the element.

Such heating elements demonstrate high efficiency and stability of operation when fully immersed in the heating medium. The increased heat transfer coefficient is achieved due to the fact that heat is generated not only in the secondary winding, but also in the primary winding and magnetic core (inductor). This allows for a more uniform distribution of the thermal load, reducing the risk of local overheating, and provides additional heating of the coolant, which increases the overall efficiency of the system.

One of the promising designs of a transformer heating element for use in decentralized heat supply systems is an element with a three-phase spatial magnetic circuit (Figure 1). The primary winding of this element is made of copper wire of rectangular cross-section and is located on the rods of the magnetic circuit (Figure 2). This arrangement provides an optimal magnetic field that evenly passes through all phases of the winding, reduces losses due to heating of the magnetic core and increases the efficiency of the heater.

In addition, the design of the element allows you to adjust the distance between the rods and the thickness of the winding, which makes it possible to adapt it to different coolants and operating conditions. This is especially important for decentralized heat supply systems, where the temperature and properties of the coolant can vary significantly. This design ensures high reliability of the heating element, long service life and efficient use of electrical energy.

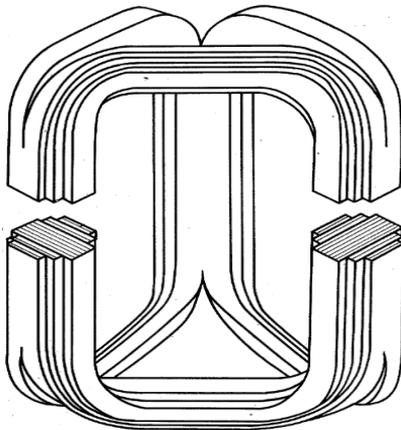


Fig. 1. Image of a three-phase spatial magnetic circuit

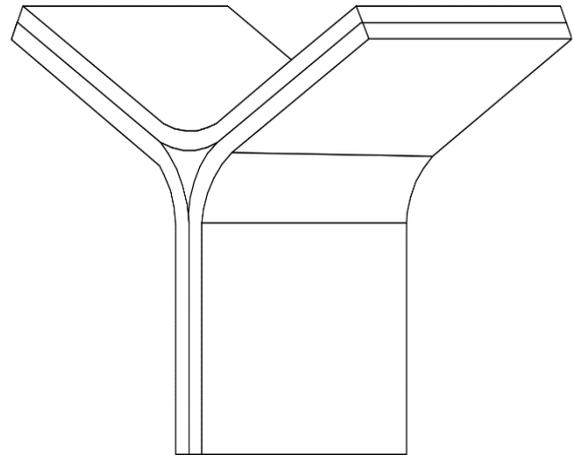


Fig. 2. A star-shaped jumper of a transformer-type heating element

According to the principle of operation of transformer heating elements, the secondary winding of the presented element has one short-circuited turn and consists of a housing shell 3 and a star-shaped jumper 4, as shown in Fig. 3. Thanks to these elements, a three-phase electrical circuit is formed, where the current flows through the contact between the housing shell and the jumper.

The ends of the wires of the three-phase primary winding are brought out through a tube 5 for connection to a source of electrical energy. To create a hermetic structure, covers 6 are installed at the ends of the element, and the internal cavity is filled with a

special filling material that provides effective heat exchange. The heat flow through the filler is transmitted from the active parts of the inductor to the housing, which is in contact with water, ensuring its heating.

To improve the thermal regime of the heating element, a tube 7 is located in the center of the jumper, through which the heated liquid circulates (Fig. 4). This design measure helps to increase the intensity of heat exchange between the coolant and the heating element due to heat transfer from the primary winding. In addition, it increases the utilization factor of the active surfaces of the element, which provides not only a more rational and efficient use of the structure, but also increases the overall efficiency of the decentralized heat supply system (NETT).

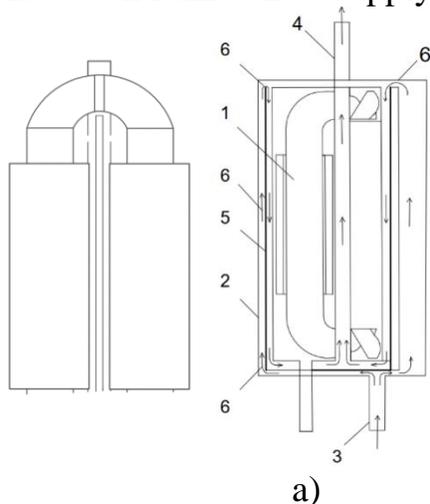


Fig. 4. - The location of the log for additional heat transfer (a) and the heating block of the heat generator (b)

Inside the heating unit there is a three-phase spatial magnetic circuit (heater) 1 (Fig. 4), which consists of a housing 2, supply pipes 3 and outlet 4, as well as a water-separating casing 5, which ensures the distribution of water flows to create optimal heat exchange conditions. Heated water 6 passes along the walls of the heat block housing, entering the channel between the heating element and the water-separating casing, where it is effectively heated to the required temperature (approximately 85 °C) in the central tube.

To ensure a high level of electrical safety, the primary winding, in addition to the standard wire insulation, has reinforced insulation in the form of a filling material, which provides additional protection against breakdown and contact with the coolant. In addition, the design solutions meet the operating conditions of heating elements in liquid media, which takes into account the possibility of scale formation and fluctuations in the properties of the coolant, ensuring reliable and stable operation of the system.

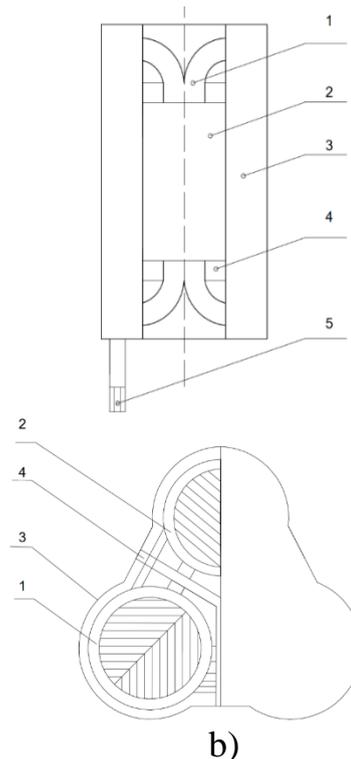


Fig. 3. Electric heating element of the transformer type with a spatial magnetic system

Conclusion. The analysis of previous studies and the considered designs of transformer heating elements allows us to draw several important conclusions regarding their use as part of the electrical complex of decentralized heat supply. The main feature of such heaters is the direct dependence of design parameters on operating conditions, in particular on the properties of the coolant and its circulation mode. To increase the efficiency and reliability of heating liquid media, it is necessary to provide a sufficiently large heat exchange area, taking into account the possibility of scale formation and other deposits, and the specific surface power should not exceed 10 W/cm² to prevent local overheating and reduce the intensity of scale deposition.

Among the numerous designs of transformer heating elements, the most promising are single-phase heaters with a capacity of up to 5 kW and three-phase elements with a sealed secondary winding. The sealed housing provides reliable insulation of the winding from the coolant, prevents corrosion and extends the service life of the element. High efficiency is achieved by generating heat in both the secondary and primary windings and the magnetic core, which provides a more even distribution of the thermal load and additional heating of the coolant.

The design of the heating element with a three-phase spatial magnetic circuit, a primary winding made of rectangular copper wire and a star-shaped jumper allows you to optimize the magnetic field, increase the utilization of active surfaces and adjust the parameters for working with different coolants. Additional elements, such as a central tube for circulating the heated liquid and a water-separating casing, improve heat exchange conditions and ensure that the required water temperature (approximately 85 °C) is achieved with high efficiency.

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