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THE THERMODYNAMIC ANALYSIS OF A SOIL HEAT PUMP HEATING AND VENTILATION SCHEME USING HEAT OF SEWAGE WATER AND VENTILATION EMISSIONS

Today, with increasing demands for construction services and thermal comfort in the space, heating, ventilation and air conditioning (HVAC) systems consume almost half of the world's energy [1, c. 51-62]. On the other hand, the increasing impact of global warming and energy shortages has prompted an immediate investigation into the efficiency and rationalization of the use of alternative energy sources in construction, especially for HVAC systems [2, c. 78-89]. Among the many forms of renewable energy (solar, wind, tidal, bioenergy and hydropower, etc.), soil thermal energy is ideally suited for direct use due to the constant heat source temperature and overall availability.

From 2010 to 2018, ground-based heat pump (HP) systems have seen a 52% increase worldwide, and by the end of 2018, they have been widely developed in 48 countries [3]. However, one of the main problems with the widespread use of such systems is the high cost of installation (well drilling, land preparation, earth probes, etc.).

From the literature review above, we can conclude that developments in this area were mainly related to the design of new design solutions that could improve the system's performance, however, such decisions have little effect on the scheme as a whole. Research should be conducted in a more fundamental direction, namely to consider the scheme from a thermodynamic point of view. For example, Bezrodnyi and Oslovskyi [4, c. 7-15] developed fundamentally new schemes of heat supply using heat pumping technologies and several low-temperature heat sources, cited the results of thermodynamic analysis of the developed schemes and investigated the optimal working conditions of the ground heat exchanger (GHE). In the study [5, c. 12-20], it was proposed to use a combination of lower heat sources such as soil, conditionally pure wastewater, ventilation emissions. As a result of such a combination, not only the operational costs for the facility's heat supply, but also the capital improvements (system installation, well drilling, the size of the GHE) improved. System performance was also improved by increasing the coolant temperature in the lower circuit. Also, this combination of heat sources allows the use of soil HP in the reversed mode in the summer - there is a phenomenon of so-called "injection" of heat into the soil [6, c. 95-103], which contributes to the further exploitation of the land compared with conventional schemes, where the topsoil could freeze, which when frozen deterioration or complete absence of soil fertility.

Continuing the research towards the creation of combined heat and power systems, a new scheme of heat supply was developed based on the ground heat pump with the additional use of wastewater heat and ventilation emissions (fig. 1).

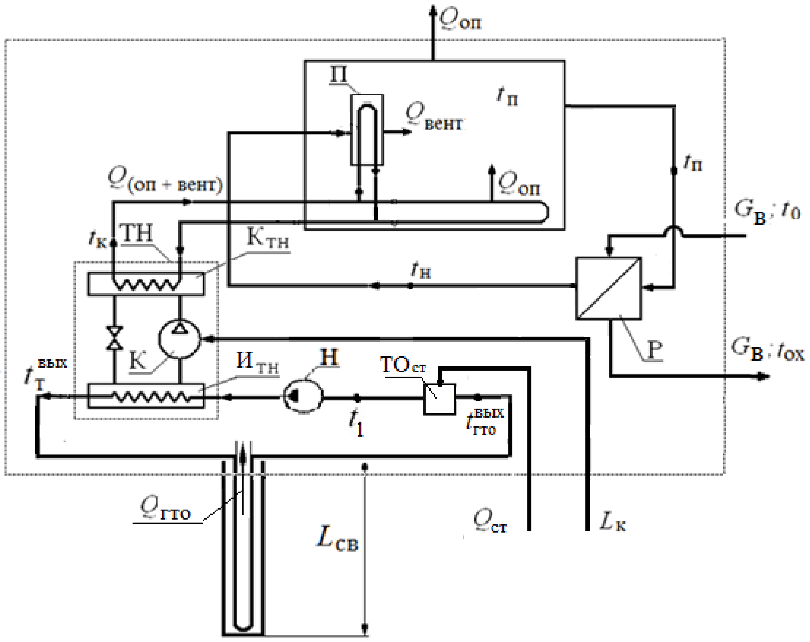

Fig. 1. Schematic diagram of the combined heating and ventilation system based on ground heat pump with the additional using of heat of ventilation emissions and wastewater: ТН–heat pump; Ктн – condenser; Итн – evaporator; К – compressor; ТОст – heat exchanger for recover heat of sewage; П–heater of fresh air; Н – pump;
Р – recuperator.

The main feature of this solution is the combination of soil HP with additional low potential energy sources, such as heat of ventilation emissions $Q_{вент}$ and wastewater $Q_{ст}$. According to the scheme, a wastewater heat exchanger (ТОст) is installed in the lower (ground) circuit of the heat pump, due to which the glycol solution, which took the heat $Q_{гто}$ from the soil, is heated from the temperature $t_{гто}^{вых}$ to t_1, thereby utilizing the waste heat of the effluents. On the other hand, a heat exchanger-recuperator (Р) is installed in the initial circuit, with which fresh atmospheric air in the mechanical ventilation system is heated from temperature t_0 to $t_н$, due to the heat of the exhaust air, which is cooled from $t_п$ to $t_{ох}$. Further, the supply air flow passes through the heater (П), where it heats up to the set temperature $t_п$ in the room.

In this scheme, due to the soil heat pump, the heat consumption is covered both for ventilation $Q_{вент}$ and for heating $Q_{оп}$. Using an additional low-potential heat sources, it becomes possible to increase the efficiency of the heat supply scheme based on soil heat pumps due to the waste heat of ventilation emissions. Due to this solution, it is possible to reduce not only the operational costs of heat supply (electricity), but also capital cost - by reducing the size of the soil heat exchanger.

The analysis of the proposed scheme was carried out using a numerical method. The algorithm of calculation on the basis of balance equations of the scheme has been developed, from which the basic quantities influencing the work efficiency have been determined. On the basis of the calculations, graphical dependences of the determinants on external factors were constructed.

As a result of the analysis the following conclusions were made:

1. The additional use of hous wastewater and ventilation emissions in general has a significant positive effect on the performance of the system.

2. The recovery of ventilation emissions not only reduces the cost of external energy for heat production, but also reduces the capital cost of constructing a ground heat exchanger for a heat pump.

3. The use of the wastewater heat exchanger practically does not affect the optimum speed in the lower circuit and operating costs, but under the calculated ambient air conditions, the utilization of such heat makes it possible to reduce the power of the ground heat exchanger, and, as a consequence, its size and the costs of its discharging. .

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