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Combination of wastewater treatment plants and heat pumps

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Abstract

An analysis of the effectiveness of the heat pumps installed in the wastewater treatment plants of Vladivostok is presented. A diagram of the urban wastewater heat utilisation apparatus is shown. The primary factors affecting the performance of heat pumps using low-temperature heat sources were identified. The economic evaluation of proposed technological solutions was implemented. The actual conditions of the use of heat pumps on the object were determined in the study. The study considered the technological characteristics of aggregates and the discharge of urban wastewater.

Keywords: Utilization of heat; Wastewater; Heat pump; Wastewater treatment

Introduction

Promising sources of heat for use in heat pumps (HP) are industrial effluents and the waste heat from municipal wastewater treatment plants. The temperature of industrial effluents is 30–40 °C; the COP of a heat pump in this case is at least 7–8. The corresponding number for industrial wastewater is usually not large. Often, these effluents contain corrosive components and require special handling, which significantly increases the cost of waste heat. City drains carry significantly more heat due to the large flow of water. The temperature of wastewater in winter is usually not more than 10–15 °C. After the wastewater passes through the treatment plants, their performance satisfies the conditions of specialized stations equipped with heat pumps; the COP of HPs in this case will not exceed 3.5–4.

A complete reconstruction of the sewerage system of Vladivostok is currently underway, including the construction of a new wastewater treatment plant. Each wastewater treatment plant can treat 160 million cubic metres of water per day and can perform multiple forms of sewage treatment: mechanical treatment, biological treatment and treatment through special filters. The special filters remove the bulk of harmful chemical contaminants. Next, water is disinfected via UV-irradiation. After treatment, the cleaned water meets all water flows through a deep issue in the Amur Bay.

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General information

Wastewater treatment plants produce a large quantity of waste heat energy. This heat should be used for heating of the residential, social and administrative buildings of the city. This heating scheme can be used after the aeration of the cleaned wastewater.

Today, the city of Vladivostok has a boiler for heating. These boiler rooms pump into the thermal network over 500 tons/hour of heated water.

The production of heat from the boiler can be reduced through the use of heat pumps. The heat of urban sewage can be used as the heat source for hot water and heating. This urban sewage solution is economically justified. The costs of preparing and operating water heating boilers are $15 million per year.

Heat pumps using heat wastewater are widely applied in Europe, the USA, Japan, South Korea, and China [1]. These heat pump units are reliable and economical sources of heat.

A schematic diagram of the wastewater treatment plant with an HP system is shown in Fig. 1. This scheme is recommended for the treatment plant in Vladivostok.

Wastewater treatment plant after pumped through heat exchangers heat pumps. After use by the HP system, the sewage passes through the conduit and flows into the sea. The drainage after the HP will not change. The temperature of wastewater is reduced by 7–10 °C. In the community, a separate heat exchanger is used to heat cold water to 60–70°. The heated water is then pumped into the thermal network of the city.

Often, the construction of a new wastewater treatment plant can be implemented without substantial reconstruction of the wastewater treatment plant. The mode of operation of the wastewater treatment plant is not affected by adding the HP system. During the summer, the HP produces 40–50% of the heat for heating the hot water supplied to the urban population.

When choosing an HP for treatment plants, one must consider the characteristics of the HP. The low-temperature water after the HP has a temperature that varies from +55 °C to +75 °C. In the climate of Russia, the water temperature in the heating network should be above +55 °C. Such a water temperature from the HP can be obtained using a special design.

The low-temperature wastewater was measured during the year. Urban wastewater is at an average temperature of approximately +20 °C in summer and +8 °C in winter.

The efficiency of the heat pump is dependent on the temperature difference between the heat source and the consumer. Fig. 2 shows the dependence of the COP φ of the HP evaporation temperature of the working fluid Te at different condensation temperatures Tc. These results were obtained for the ideal Carnot cycle:

$$\varphi = \frac{T_C}{T_C - T_E},$$

and the empirical formula V. Martynovsky [2]:

$$\varphi = 0.74\frac{T_C}{T_C - T_E} - (0.0032T_E + 0.765T_E/T_C) + 0.9$$

The efficiency of the HP significantly depends on the temperature of the heat source. In summer, the temperature of the wastewater is high. As a result, the conversion efficiency is high. In this case, the HP can heat the water at low energy costs. In the summer, most of the load is addressed by the heat pumps. With an increase in the consumption of heat, the boilers are used in the gas boiler. The HPs reduce the fuel consumption for the preparation of water for the heating network.

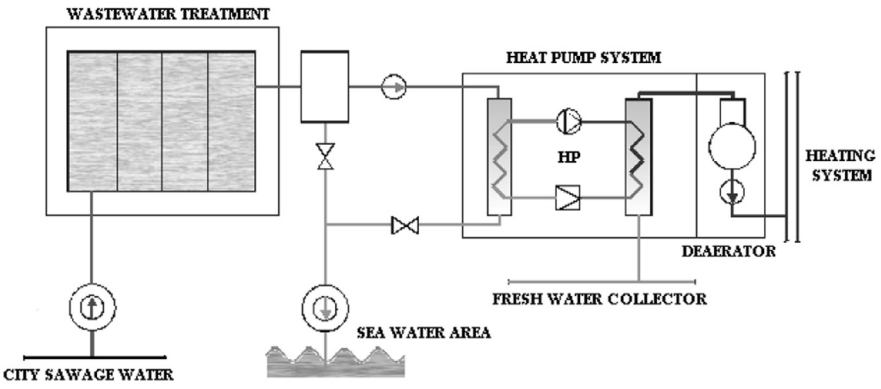

Fig. 1. Installation diagram HP for wastewater treatment plants.