Demonstration and laboratory complex for the production of heat energy using sources of unconventional and waste energy

L V Plotnikova^{1,*}, *A A Faizullin*¹, *A S Gavrilov*¹ and *N M Hacıbalayev*²

¹Kazan State Power Engineering University, 51 Krasnoselskaya Street, Kazan, Russia

²Sumgait State University, 43rd block, AZ5007, Sumgait, Azerbaijan

Abstract. The description of the work of a laboratory unit for the production of thermal energy that simulates the use of solar energy and the use of wastewater energy is presented. The installation includes a heat pump, solar collector and waste water tank. Presents options for wiring elements of the unit.

1 Introduction

Demonstration and laboratory complex Viessmann is designed to release thermal energy from a source of low-potential thermal energy to a consumer with a higher temperature. As a source of low-potential thermal energy, the installation simulates unconventional energy and waste energy [1, 2] of enterprises – solar energy and wastewater energy, respectively. As a consumer is considered a hot water system of the building. The basis of the installation that increases the potential of the energy source is a heat pump. This installation for the preparation of hot water supply is located at the Department of Industrial Heat Power Engineering and Heat Supply Systems of Kazan State Power University in the auditory B-214 (Figure 1).

The basic configuration of the laboratory installation (Figure 1 (a)) includes a heat pump with a Vitosolic 200

control unit (Figure 1 (b)), a cubic tank, 2 buffer tanks, a solar collector, a Vitosolic solar control system, Wilo and Grundfos circulation pumps, instrumentation equipment. The main site of the collection of low-potential thermal energy is the solar collector.

Two options were considered for switching on the heat pump into the laboratory unit for the production of heat energy in order to increase the energy potential of the source [1–3]; their schemes are shown in the figures below.

2 Installation scheme, simulating the use of wastewater energy

One of the proposed configurations of the laboratory-demonstration complex is an installation that simulates the use of wastewater energy for hot water supply [4] (“water-to-water” type) (Figure 2). The use of

a)

b)

* Corresponding author: mikhailovalv@mail.ru

Fig. 2. Installation diagram with the inclusion of a heat pump and solar collector: IR heater – infrared heater; SC – solar collector; Tank – cubic tank with simulated wastewater; HP – heat pump; HWS – hot water supply.

wastewater energy is important, because they have significant resource volumes [5 – 7] and have a permissible temperature for use in a heat pump. The temperature of wastewater is much higher than the temperature of geothermal energy, which indicates the possibility of using more heat per unit volume of the energy source [2]. The simulated wastewater is located in the tank of the laboratory unit, and its heating to the temperature of the real wastewater is provided by a circuit with a solar collector. The installation is complemented by an infrared heater to simulate solar energy.

The installation (Figure 2) works as follows. In the solar collector Vitosol 100-F with an area of 2.51 m², the water of the circulation circuit is heated by radiation from an infrared heater BIH-L-3.0. The heated water from the boiler of the Vitocel 100-E solar collector is sent to a vat tank. In it, tubes with a coolant pass through the entire internal volume of the tank and maintain the required temperature of the water in the tank. Next, there is a heat exchange between the water in the tank and the water in the tubes of the Vitocal 300-G heat pump. The heated water enters the housing of the heat pump, it gives off heat to the intermediate coolant in the evaporator of the heat pump. As the intermediate heat carrier R407C freon is used. Next, the waste chilled water is returned to the tank to raise the temperature. The evaporated freon is compressed in a heat pump compressor in order to increase the energy potential of this intermediate coolant. Next, high-potential freon in the heat pump condenser transfers heat to the water from another installation circuit, which is sent to the Vitocell 100-E buffer tank and then goes to the needs of hot water supply HWS.

To achieve the required temperature of hot water for the needs of HWS of 55 °C in this laboratory installation, a heat source of 38 °C is required. This was confirmed experimentally (table 1). The temperature of the simulated water in the bottom of the tank varied from 20 °C to 40 °C, while the readings of the primary and secondary sources of heat were taken from the control panel of the heat pump (Figure 1 (b)).

Table 1. Experimental indicators of coolant temperatures.

The temperature of the source – of the “waste water” in the tank, °C	Experimental water temperature for HWS, °C
20	45
25	48
30	51
35	53
38	55
40	56

As a result, it can be concluded that the use of wastewater in this installation configuration will not provide the desired temperature HWS. The temperature of wastewater at enterprises varies between 18 – 30 °C, which in this installation gives the temperature on the HWS within 45 – 51 °C. This is due to the significant loss of thermal energy during its transfer inside the tank and the presence of several heat exchange circuits. In addition, in this scheme (Figure 2), solar energy is used only for heating water that simulates wastewater, and it is not possible to estimate the efficiency of solar energy use in heat pump installations. In this regard, it was decided to upgrade the original inclusion scheme (Figure 3).

3 Installation scheme, simulating the use of solar energy and wastewater energy

The upgraded configuration of the laboratory-demonstration complex is an installation that simulates the simultaneous use of solar energy and wastewater energy for hot water supply (“air – water” type and “water – water” type) (Figure 3).

So, it was experimentally revealed that to achieve the required temperature of hot water for the needs of HWS of 55 °C in this laboratory installation, a heat source of 38 °C is required. In this regard, it is proposed to connect the solar collector directly to the heat pump, bypassing the cube capacity. The solar collector provides the required temperature for the heat pump evaporator at 38

Fig. 3. Installation diagram with the inclusion of a heat pump, solar collector and tubular electric heater: IR heater – infrared heater; SC – solar collector; Tank – cubic tank with simulated wastewater; TEH – tubular electric heater; HP – heat pump; HWS – hot water supply.

°C. Also in this installation configuration (Figure 3) there will be no decrease in the water temperature due to heat exchange in the additional circuit of the tank, which was in the previous installation configuration (Figure 2).

Thus, the line “Infrared heater - solar collector - boiler - heat pump - boiler - consumer HWS” - is the first line of this laboratory installation, operating on unconventional energy - solar energy.

The second line of the laboratory installation operates on simulated waste energy flows - wastewater and is a chain: “Tubular electric heater - bottom tank - heat pump - boiler - HWS user”.

Consequently, the tank remains in the installation. But the source that heats the water in the tank is not the solar collector, but the tubular electric heater. In this case, both lines can operate simultaneously.

4 Conclusions

The calculation of the upgraded configuration of the laboratory unit with a heat pump at a temperature of the heat source of 38 °C (table 2) was carried out. It can be

seen that this laboratory installation can satisfy the need for hot water supply for the building body by 7 % during the heating period and by 12% during the non-heating period, that is, provide several laboratory rooms with hot water.

Thus, the selected installation configuration (Figure 3) uses solar energy for use in the heat pump directly, and not just to simulate the heat of wastewater [8 - 10]. The heat of sewage is simulated by water in a bottom tank, heated by a tubular electric heater.

The presence of additional equipment in the form of a solar collector, connected directly to the heat pump through the buffer capacity, provides an increase the temperature of the coolant fed to the heat pump. This increases the efficiency of the heat pump, as well as extends its service life. The presence of a tubular electric heater immersed in the tank, will not only, if necessary, maintain the desired temperature of the water inside the tank, but also create 2 separate circuits that will allow to conduct visual experiments with the installation.

This installation with a heat pump can be used not only to meet the needs of hot water supply to buildings,

Table 2. Calculation results.

Parameter	Value	Unit of measurement
Heat flow to the hot water supply of the housing B of the KGEU for the heating period	35.77	kW
Heat flow to the hot water supply of building B of the KGEU for a non-heating period	22.89	kW
Specific heat load of the heat pump evaporator	150	kJ/kg
Specific heat load of the heat pump condenser	209	kJ/kg
Heat pump heat conversion coefficient	4.2	–
Thermal load of the solar collector	2.73	kW

but also in a number of industries [11 - 15]: for the utilization of the wastewater heat, for the utilization of the intermediates products heat in petrochemical, food, pulp and paper enterprises, etc.

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