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CALCULATION OF ENERGY SAVING WHEN USING A HEAT PUMP UNIT IN SOLAR GREENHOUSES

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Abstract. *The article discusses energy-saving issues and schematic diagrams in solar greenhouses' heat-cooling supply systems using heat pump installations. The main directions of energy saving have been identified and an alternative system of heat-cooling supply of a solar greenhouse with a heat pump installation has been developed. Shown questions energy savings are considered in the system heat chill of the provision vegetable vault with the use of heat pumping installation. Based on the research analysis, existing systems heat chill of the provision solar greenhouse revealed main trends in energy savings and is designed alternative system heat chill of the provision solar greenhouse with heat by pumping installation.*

Keywords: *energy saving, heat supply, heating, heat pump, efficiency, rural solar house, energy balance, energy resource, hot water supply, heat-cooling supply, cold source, hot heat carrier.*

Introduction

More than half of all natural gas produced is spent on residential, public, and industrial buildings' heat-cooling supply of vegetable stores and refrigerators, and low-temperature thermal processes in various industries and agricultural production [1].

Therefore, energy saving using heat pumps that use thermal energy dissipated in the environment or utilizing secondary energy resources for heat-cooling supply to various industries and agricultural production at the lowest cost is an urgent problem.

Using heat pumps for heating, hot water supply, and heat-cooling supply is an alternative to other methods, such as traditional fossil fuel combustion, central steam or water heating, electric heating, etc. [2].

Methods and Materials

A heat pump is a device that allows you to transfer heat from colder to hotter due to the use of additional energy (most often mechanical). Using heat pumps is one of the crucial ways to recycle heat from secondary energy resources [3].

It is known that the heat of low potential is a product of the human's technical activity, and the lower its temperature level, the more this heat is irretrievably lost, dissipating in the environment. Examples of heat carriers include heated air entering the atmosphere from ventilation and air-conditioning systems or warm domestic and industrial wastewater at a temperature of approximately 20-40 °C. Often, the only economically viable way to utilize the heat of such secondary energy resources is by using heat pumps. Heat pumps can use the heat generated by various technical devices and the heat of natural sources - air, the water of natural water bodies, ground, and solar radiation [4-9].

The main application of heat pumps at present is heating of the coolant for heating, ventilation, and hot water supply systems of buildings. However, they can also be used for technological purposes.

The greatest energy and economic benefits from heat pumps can be achieved by using complex heat systems - and cooling systems when obtaining cold and heat at any possible temperature level possible for this system.

The work aims to develop a concept diagram of a solar house with solar greenhouses, solar panels, and a solar water heating installation.

The most appropriate energy analysis option is the simultaneous mode of both consumers' existing cooling and heating needs, which can be connected via a heat pump. Air-conditioning periods in a solar farmhouse and the operation of greenhouses are well combined, as the greenhouse is a consumer of heat, and the other requires cooling (Fig. 1).

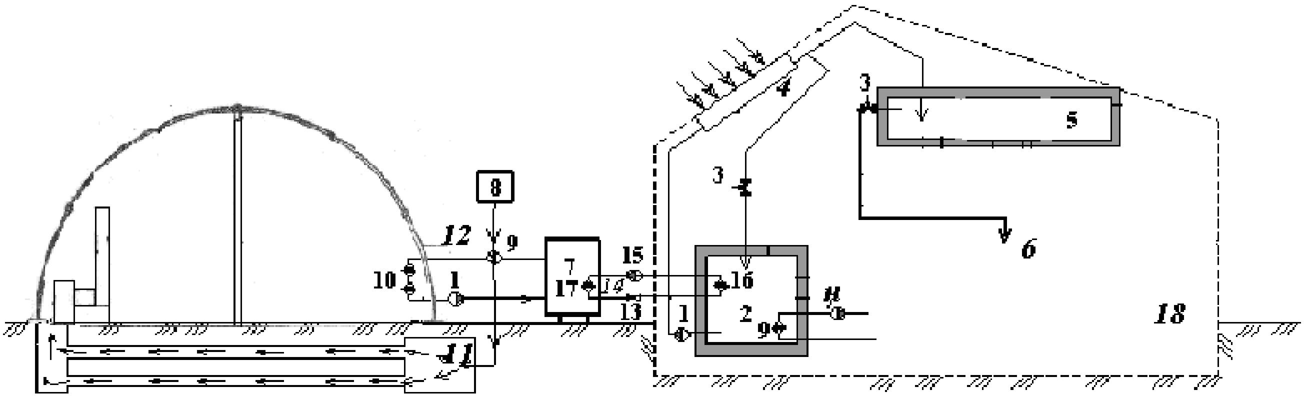

Fig. 1. Schematic diagram of the heat and cooling system of the solar farmhouse with solar greenhouses.

1-circulating pump; 2-accumulating hot water tank; 3-electromagnetic valves; 4-solar water heater; 5-tank of hot water for heating of rural house; 6-consumer of hot water; 7-tank of hot water for heating of greenhouse; 8-small boiler - the source of heat of flue gases; 9-water heat exchanger; 10-heating apparatus; 11-intrasoil heat storage channel; 12-solar greenhouse; 13-regulating heat pump valve; 14-pump installations; 15-heat pump compressor; 16-heat pump's condenser; 17-heat pump capacitor; 18-solar rural house.

In the joint heat system - and cold supply of greenhouses and rural solar house 18, a heat pump (HP) 14 is installed between solar house 18 and greenhouse 12. Solar house 18 is cooled with HP, 14 the heat of ventilation emissions is removed by the evaporator HP 16. Then the refrigerant vapor is compressed in the compressor 15 and becomes overheated. The HP 17 condenser is immersed in storage tank 2, where the refrigerant vapor condenses and the water is heated up to 50-60 °C. With the help of circulation pump 1, hot water from storage tank 2 passes through the water heat exchanger 9, where it is reheated by flue gases 8 to a temperature of 90-100 °C and enters heater 10 of the greenhouse. If necessary, the cooled combustion product 8 can be fed through the subsoil heat storage channel 11, and then into the conservatory for plant nutrition with carbon dioxide. Solar water heater 4 is designed for heating a solar house and is regulated by valves 3 and 13.

Results

We have proposed a heat pump system to save energy and create an autonomous heat supply for a rural residential building. Like a refrigeration machine, a heat pump consumes energy to implement a thermodynamic cycle (compressor drive). The conversion factor of a heat pump - the ratio of heat output to electricity consumption - depends on the temperature level in the evaporator and condenser and varies in different systems in the range from 2.5 to 5, i.e., for 1 kW of electrical energy consumed, the heat pump produces from 2.5 to 5 kW of thermal energy. The temperature level of heat supply from heat pumps is 35-55°C. Saving energy resources reaches up to 70%.

The industry of technically developed countries produces a wide range of vapor-compression heat pumps with thermal power from 5 to 1000 kW.

The energy balance of HP is written as follows:

$$Q_{con} = Q_{evap} + L_{comp} \qquad (1)$$

where, Q_{con} - heat removed from the condenser;
Q_{evap} - heat supplied to the evaporator;
L_{comp} - compressor operation.

The HP conversion factor is determined by the formula:

$$\phi = Q_{con}/L_{comp} = \alpha \cdot T_{con}/(T_{con} - T_{evap}) \qquad (2)$$

where, T_{con} - condensation temperature of the working medium;
T_{evap} - evaporation temperature of the working medium;
L_{comp} - compressor operation.
α - total HP loss factor (cycle losses, compressor losses, losses from irreversibility during heat transfer, etc.).

Ideal HP conversion ratio:

$$\phi = T_{con}/(T_{con} - T_{evap}) \qquad (3)$$

Heat supply systems using heat pumps - heat transfer heat supply systems - can be used for heating, heating ventilation air, heating water for hot water supply, etc.

The following can be used as low-potential (low-temperature) heat sources:

a) Secondary Energy Resources (SER):
- the heat of ventilation emissions;
- the heat of grey sewage;
- the waste heat of technological processes, etc.

b) Non-conventional Renewable Energy Sources (NRES):
- the heat of the surrounding air;
- the heat of the ground and geothermal waters;
- the heat of water bodies and natural water flows;
- the heat of solar energy, etc.;
- the heat of the surface and deeper layers of the soil.

It should be noted that using heat pumps for heat and cold supply using SER and NRES is a new modern technology and requires modern architectural and planning, design, and engineering solutions for the entire facility. TCT should be organically integrated into the facility and rationally interfaced with the rest of the engineering systems of the facility.

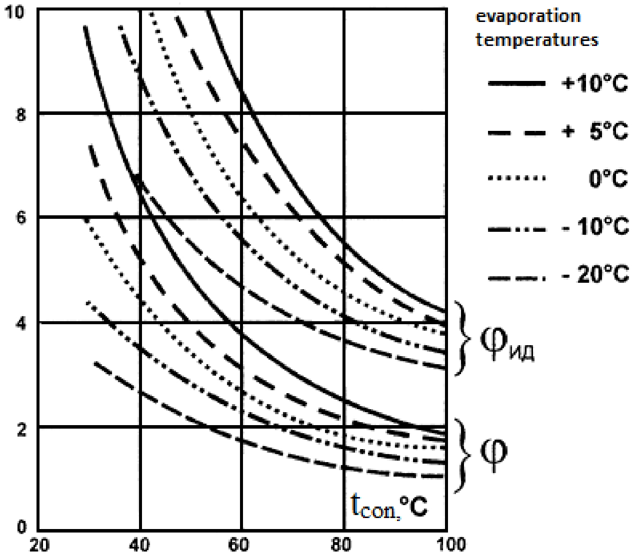

Fig. 2. Dependence of ideal and real (genuine) HP conversion coefficient on refrigerant evaporation and condensation temperatures

Discussion

Consider the method of calculating heat pumps

Initial conditions: heat demand of a one-story rural house with an area of 100 m^2 (depending on thermal insulation) P=12 kW [9]; the water temperature in the heating system must be 60°C. A heat pump with a capacity of 14.5 kW (the nearest larger standard size) was selected for heating the building, which consumes 3.22 kW of energy to heat the freon. The heated volume of the building is V=300 m^3.

The annual heat load for the heating period of Karshi City for 132 days is:

Q = p · τ = 12 · 132 · 24 = 38016 kW · hour or Q = 38,016 MW · hour

If we translate to 38,016 · 3,6 = 136,8 MJ

The main energy characteristics of the heat pump are the heat conversion (transformation) coefficient, thermodynamic efficiency, and unit cost, i.e., the cost attributed to the heat capacity of the heat pump.

The heat conversion coefficient is the ratio of the received thermal power to the power expended to drive the compressor. It is higher than one and depends significantly on the temperature of the cold heat source T_1 and the temperature of the obtained hot coolant T_2. As a result of the operation of the heat pump, we can get about 2÷8 times more heat than in the case of the direct heating of the coolant in the electric heater [4, 5]: The heat transfer ratio of the heat pump is equal (Fig. 2):

$$\varphi_T = \frac{Q_B}{N} \tag{4}$$

where, Q_B - received thermal power, kW;

N - power input on the compressor drive, kW;

$$Q_B = Q_0 + N \tag{5}$$

where, Q_0 - heat received from a low-potential source, kW;

Let us determine the fuel savings when using a heat pump installation for heating instead of a boiler room. Thermal load Q_B = 12kW at water temperature in supply pipeline τ_1 = 60°C. Heat pump transformation coefficient φ = 4,7; Power grid efficiency η_C=0,95; Boiler room efficiency η_K=0,85.

The power consumed by the electric motor of the compressor of the heat pump unit,

$$N_{EC} = QB\varphi = 124{,}7 = 2{,}55\ kW \qquad (6)$$

Power consumption, taking into account losses in power grids

$$N_E = N_{EK}\eta_C = 2{,}55 \cdot 0{,}95 = 2{,}7\ kW \qquad (7)$$

Fuel consumption in the boiler room to produce 136,8 MJ of heat:

$$B_K = \frac{Q_B}{Q_B\eta_K} = \frac{136{,}8}{29{,}3 \cdot 0{,}85} = 5{,}5 \text{ kg reference fuel/h}$$

Reference fuel saving

$\Delta B = B_K + B_T = 5{,}5 - 1{,}03 = 4{,}47$ kg/h or energy savings due to the use of a heat pump during the heating period is:

$\Delta B = 4{,}47 \cdot 132 \cdot 24 = 14160$ kg or 14.1 tons of conventional fuel.

Conclusion

We choose a heat pump type «water-water» based on the studies and calculations. Thus, the developed heating system with a heat pump allows Karshi City to save 14 tons of conventional fuel per rural house with a heating area of 100 m^2 for one heating period.

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