EFFICIENCY OF USE OF HEAT PUMPS

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ANNOTATION

The article discusses the advantages of using a heat pump, studied the principles of operation of heat pump installations and the technical and economic efficiency of heat pumps using the example of a vapor compression heat pump.

Keywords: heat pump, thermal energy, heat engine, economic efficiency, temperature.

INTRODUCTION

It is well known that when transferring thermal energy from a less heated medium (low-potential source of thermal energy) to a more heated one (consumer coolant), the heat pump consumes energy, however, in volumes that are significantly less than it transfers to the heated medium.

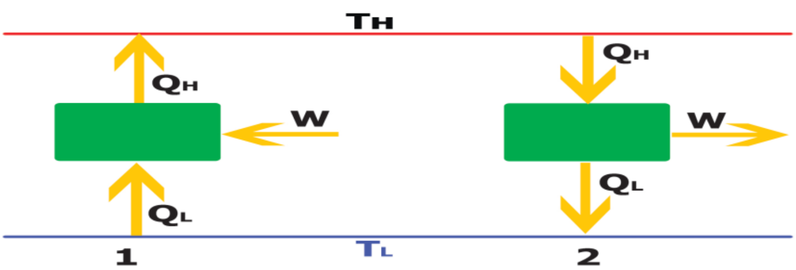
The heat pump, taking heat energy from the ventilation emissions of the building with a temperature of 20°C (and, accordingly, cooling them) and spending 1 kW of electricity, can receive and transfer to the heating system up to 4 kW of heat energy with a temperature of 80-90°C (provided that that the ventilation emissions contained such an amount of thermal energy).

In other words, a heat pump installation makes it possible to use the low-temperature thermal energy of the soil, air, water, domestic wastewater, mine water, industrial discharges and much more. The most important feature of the heat pump installation is its versatility in relation to the type of primary energy.

The main circumstance in the implementation of such projects is the availability of a source of low-temperature thermal energy and the economic efficiency of the project itself.

The popularity of the heat pump has arisen largely due to the fact that thermal energy is obtained directly at the installation site of the equipment. With high environmental friendliness (no noise, vibration, odors, fire), it has a high degree of fire and explosion safety, because there are no fuel combustion processes and emissions of combustion products. Heat pumps do not require the laying of fuel (gas) lines and smoke exhaust systems, and therefore, the corresponding costs [1].

Currently, more than 30 million heat pumps of various capacities are operating in the world - from a few kW to hundreds of MW. In the US, more than 30% of residential buildings are equipped with heat pumps (combined heating and air conditioning systems based on heat pumps). In Sweden, more than 100 heat pumps (from 5 to 80 MW) have been put into operation in recent years. In Japan, 3 million heat pumps are sold annually (compared to 1 million in the US).



Rice 1. Thermodynamic diagram of a heat pump (1) and a heat engine (2).

All heat engines (internal combustion engines, refrigeration, steam, etc.) operate cyclically. Graphically, a cyclic process (cycle) is depicted as a closed line. In thermodynamics, cycles are considered, consisting of a strictly defined sequence of some simple processes (isothermal, isochoric, isobaric, adiabatic), as a result of which the working fluid returns to its original state [2].

The heat engine (rice 1) receives heat Q_H from a high-temperature source and releases it Q_L at a low temperature T_L, giving useful work W. The heat pump requires work W to receive heat Q_L at a low temperature T_L and release it at a higher temperature T_H.

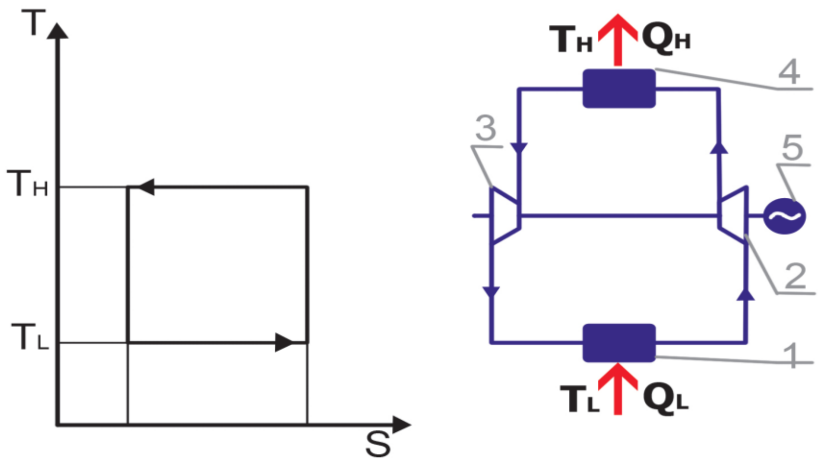
It has been proved that if both of these machines are reversible (i.e., the thermodynamic processes do not involve heat or work losses), then there is a finite limit to the efficiency of each of them, and in both cases this is the ratio Q_H/W.

In other words, one could build a perpetual motion machine simply by connecting one machine to another. Only in the case of a heat engine, this ratio is written in the form of W/Q_H and is called thermal efficiency, and for a heat pump it remains in the form of Q_H/W and is called the heat conversion coefficient (K_T) [3].

During the experiment, heat was isothermally supplied at a temperature of T_L and isothermally removed at a temperature of T_H, and compression and expansion were performed at constant entropy (rice 2), with the supply of work energy from an external engine. In this case, the transformation coefficient for the Carnot cycle will look like:

$$K_T = T_L/(T_H - T_L)+1= T_H /(T_H - T_L)$$

That is, at T_H = 70+273=343 K and T_L = 5+273=278 K, we get K_T = 343/65 = 5.3 and can be higher only with a decrease in T_H and/or an increase in T_L.

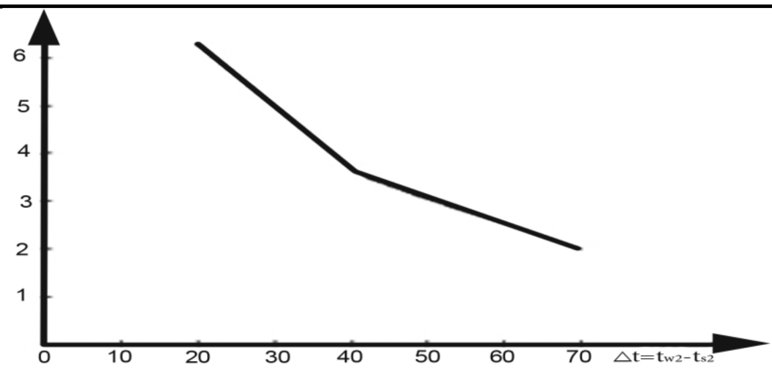


Rice 2. Schematic diagram of a vapor compression heat pump.

1 - evaporator; 2 - compressor; 3 - capacitor; 4 - expansion machine (expander); 5 - electric drive

So, in fact, at given temperatures, no heat pump can have a better performance, and all practical cycles only realize the desire to get as close as possible to this limit.

Vapor compression and absorption heat pumps for the implementation of thermodynamic cycles consume various types of energy: Vapor compression - mechanical (most often electrical), absorption heat pumps - thermal. Such an indicator can be the specific fuel consumption for heat generation or the coefficient of its use. This approach is also justified because the base power plants are thermal, operating on fossil fuels [4].



Rice 3. Dependence of the conversion factor φ of the PTH on the temperature difference between heated water (t_{w2}) and chilled water (t_{s2})

The energy efficiency of the PTN is characterized by the energy conversion coefficient

$$\varphi = Q_{п}/Q_{к}$$

where $Q_{п}$- produced heat; $Q_{к}$ - power in thermal equivalent spent on the compressor drive.

This means that the value of the vapor heat pumps conversion factor (φ) depends mainly on the temperatures of the low-temperature heat source and the temperature of the heated medium at the outlet of the heat pump (rice 3). The greater the temperature difference between the heated and cooled media, the lower the efficiency of the vapor heat pumps.

Based on the foregoing, it can be argued that heat pumps are high-tech equipment that is distinguished by economic efficiency, environmental safety, excellent energy efficiency, and comfort throughout the entire service life.

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