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STUDY OF THE EFFICIENCY OF USING A HEAT PUMP IN THE HEAT SUPPLY SYSTEM OF A PRIVATE HOUSE

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Summary. *Currently, air-to-water heat pumps are in high demand, which, thanks to the high coefficient of heat conversion, reduce energy consumption and negative impact on the environment. The advantages of using a heat pump are safety, environmental friendliness, economy, and the fact that when using it, dependence on rising prices for natural energy sources is reduced. One of the main problems of the air-to-water heat pump is a decrease in productivity when the outside air temperature drops in winter. This paper analyzed the efficiency of air-to-water heat pump Mitsubishi Electric PUHZ-SHW230YKAR1 for providing a private house with heating, hot water supply and air conditioning. On the basis of the obtained results, graphs of the efficiency of the heat pump were constructed depending on the temperature of the environment and the coolant. The installation is able to generate heat at an external temperature of minus 28°C. The maximum heating temperature of the coolant is 60°C.*

Key words: *heat pump, energy saving, coolant, air conditioning, hot water supply, energy efficiency, thermal performance, power consumption, split system.*

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Statement of the problem in a general form and its connection with important scientific or practical tasks. Energy-saving technologies are slowly but surely replacing traditional types of heating. The use of heat pumps is one of the promising directions among sources of non-traditional energy due to the possibility of using renewable energy technologies from environmental sources. The use of heat pumps allows you to limit the consumption of nonrenewable fuel resources, reduce the negative impact on the environment, and improve the quality of heat supply [1–5].

Unlike a boiler, convector and other types of heaters, a heat pump unit does not produce heat. It transfers heat from one environment to another. A heat pump consumes electricity and generates heat. The ratio of these indicators characterizes its performance. But the real efficiency of the heat pump can vary significantly. The lower the temperature at the inlet and the higher the temperature at the outlet, the lower the efficiency. When using a heat pump that uses air low-potential energy, it is possible to provide the house with heating, air conditioning and hot water supply in a complex [6–7].

Analysis of recent research and publications. Rational use of fuel and energy resources is an important global problem at present. One of the ways to solve it is the use of modern energy-saving technologies that use renewable energy sources. According to data from the International Energy Agency (IEA), about 45 million heat pumps were sold in 2021 [8–9].

According to experts' estimates, it can be stated that more than 80% of thermal energy for heating systems and hot water supply in developed countries as of 2025 will be produced by heat pump units that use various types of low-potential heat sources [10].

The use of heat pumps is increasing every year in the world. The air heat pump is currently an effective and ecological way of using the renewable energy of the environment. Using atmospheric air as the bottom energy source for a heat pump is an advantage because it is a free and unlimited source. Heat pumps, in which the source of energy is air, are very dependent on the temperature of the outside air in comparison with heat pumps that draw energy from the soil or water bodies [11].

Currently, there are not enough materials related to the specifics of the use of heat pump units, so there was a need to conduct a study.

The purpose of the work is: to investigate the peculiarities of using the Mitsubishi Electric PUHZ-SHW230YKAR1 heat pump in the heat supply system of a private house.

Setting objectives. In world practice, the most promising technologies in heat supply systems are technological solutions using heat pump units (HPU). A heat pump is a device for transferring thermal energy from a source with a lower temperature to a source with a higher temperature, which allows using the low-temperature thermal energy of the soil, air, water, domestic sewage, mine water, industrial discharges to obtain a heat carrier suitable for heating and cooling of premises, buildings, structures. At the same time, by spending 1 kWh of electricity for the operation of the pump, you can get about 2.5–3.5 kWh of thermal energy [12–13].

The total installed capacity of heat pumps today is 15723 MW with an annual heat production of $86,673\times10^{15}$J [2]. The installed capacity of geothermal heat pump systems [3] is about 6700 MW during energy production in the amount of $23,3\times10^{15}$J/h.

Such a large volume of HPU use in developed countries is explained by the significant advantages of heat pump installations over other heat supply systems, because they [16]:

- have a high degree of automation;
- distinguished by high reliability, well-established production and maintenance system;
- are highly efficient (from 3 to 8 kW of thermal energy can be obtained for each kilowatt of electrical energy spent on the compressor drive, depending on the temperature of the low-potential source) [17];
- have a high level of factory readiness of equipment, available installation, connection and maintenance [18].

Research was conducted on the effectiveness of using the Mitsubishi Electric PUHZ-SHW230YKAR1 air-to-water heat pump of the ZUBADAN series depending on the outdoor air temperature, °C, for Khmelnytskyi city. The private house where the research was conducted has an area of 250 m^2.

A split system consisting of internal and external units was investigated. A feature of this heat pump model is a modern R1 compressor and the ability to work on heating at low temperatures – up to minus 28°C. Almost 90% of the consumed power is accounted for by the compressor. The efficiency and productivity of the heat pump depends on the power consumption. Compressors should be energy-efficient and low-noise.

The compressor in this model is a hybrid spiral design with a through shaft, which effectively combines the «compression method» of a spiral compressor and the «mechanism design» of a rotary compressor, while eliminating the shortcomings and imperfections of each type [19].

One pressure sensor, Pa, and two temperature sensors, °C, are installed in the heat pump for research. One temperature, °C, outdoor air sensor and one remote sensor are also included. In addition, the electric power of the heat pump *PI*, kW, was measured.

From the received data from the sensors, depending on the temperature of the outside air t_{ext}, °C, and the water at the outlet t_w, °C, the thermal productivity *TC*, kW, and the heat conversion coefficient COP (Table 1, Fig. 3) were calculated and the power consumption *PI*, kW, was recorded (Table 1, Fig. 4).

The obtained data in Figure 3 show that it is most profitable to use a heat pump with systems where the temperature of the coolant at the outlet does not exceed 50°C [19]. When the outside air temperature is not lower than minus 5°C, the heat pump remains effective at a higher temperature of the coolant at the outlet – up to 60°C.

Table 1

The results of determining the thermal productivity TC, kW, power consumption PI, kW, and the coefficient of heat conversion COP of the heat pump Mitsubishi Electric PUHZ-SHW230YKAR1 at 12 kW depending on the temperature, °C, the surrounding air t_{ext} and the coolant at the outlet t_w

t_{ext}, °C	t_w, °C																	
	35			40			45			50			55			60		
	TC, kW	*PI*, kW	*COP*	*TC*, kW	*PI*, kW	*COP*	*TC*, kW	*PI*, kW	*COP*	*TC*, kW	*PI*, kW	*COP*	*TC*, kW	*PI*, kW	*COP*	*TC*, kW	*PI*, kW	*COP*
-25	11,2	4,82	2,33	10,94	4,96	2,22	10,23	4,98	2,06	9,84	5,23	1,89	-	-	-	-	-	-
- 20	11,7	4,12	2,84	11,16	4,13	2,68	10,63	4,21	2,54	10,12	4,70	2,16	-	-	-	-	-	-
-15	12,0	3,76	3,21	11,33	3,74	3,02	10,91	3,83	2,86	10,30	4,42	2,32	-	-	-	-	-	-
-10	12,0	3,34	3,61	11,67	3,56	3,28	11,46	3,85	2,99	11,15	4,49	2,49	11,12	5,32	2,06	-	-	-
-5	12,0	3,14	3,83	11,86	3,48	3,43	11,82	3,86	3,07	11,68	4,54	2,57	11,68	5,25	2,24	-	-	-
33	12,0	3,02	3,98	12,01	3,42	3,53	12,01	3,86	3,12	12,01	4,56	2,63	12,01	5,08	2,28	11,21	5,48	2,01
0	12,0	2,95	4,07	12,01	3,38	3,55	12,01	3,82	3,14	12,01	4,45	2,69	12,01	5,02	2,32	11,94	5,64	2,10
33	12,0	2,73	4,39	12,01	3,21	3,76	12,01	3,68	3,26	12,01	4,26	2,80	12,01	4,88	2,34	12,00	5,41	2,16
55	12,0	2,63	4,53	12,01	3,13	3,84	12,01	3,58	3,33	12,01	4,19	2,88	12,01	4,86	2,6	12,00	5,23	2,21
110	12,0	1,93	6,21	12,01	2,63	4,56	12,01	2,62	4,58	12,01	3,37	3,56	12,01	3,92	3,09	12,00	4,31	2,61

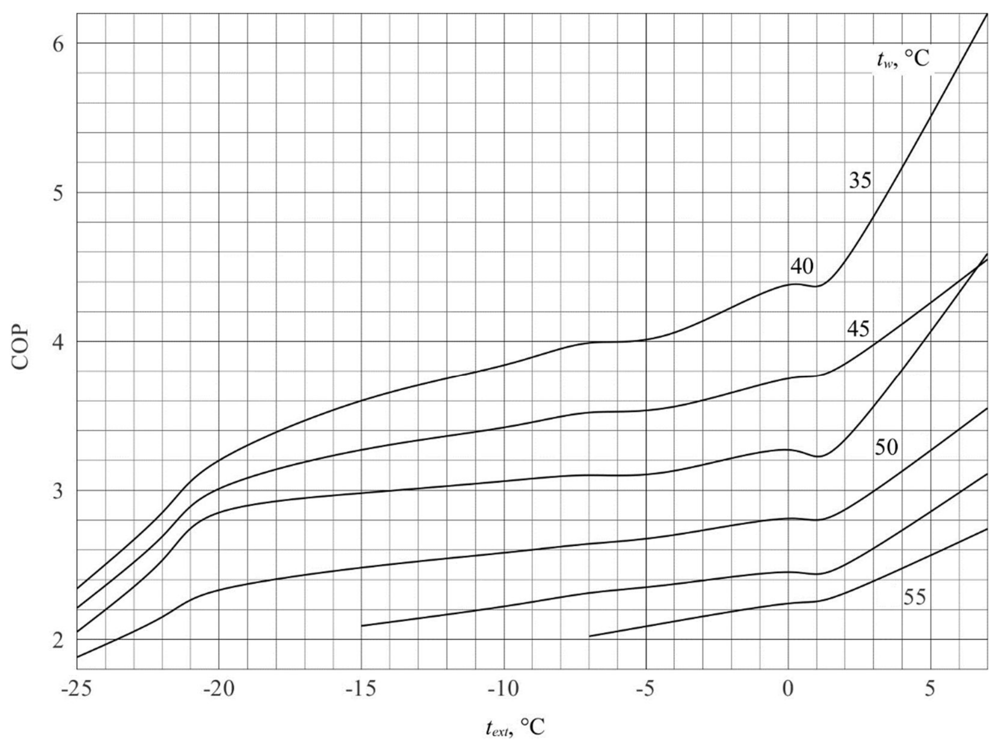

Figure 1. Dependence of the conversion coefficient COP on the temperature of the outside air t_{ext}, °C, and the temperature of the water at the outlet, t_{ext}, °C

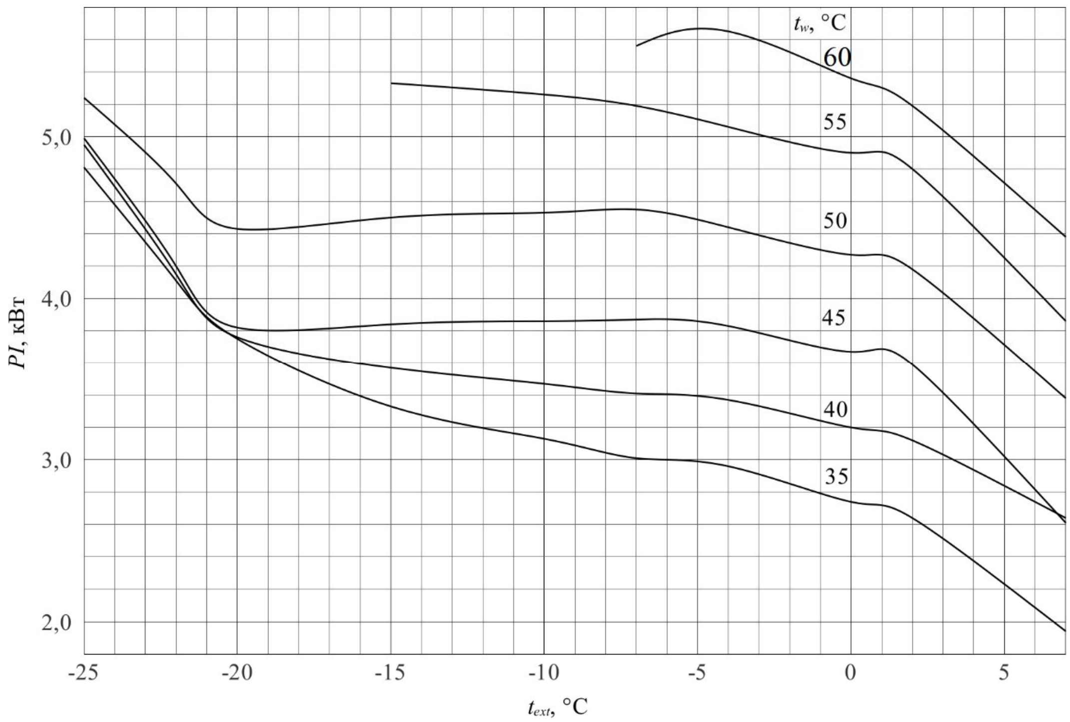

Figure 2. Dependence of the consumed power *PI*, kW, on the temperature of the outside air t_{ext}, °C, and the temperature of the water at the outlet t_w, °C

Fig. 2. Dependence of the consumed power *PI*, kW, on the temperature of the outside air t_{ext}, °C, and the temperature of the water at the outlet t_w, °C

An electric heater with a capacity of 6 kW is provided in the design of the heat pumps to supply the consumer with uninterrupted hot water. It allows you to heat the water to the required temperature t_w, °C at a low temperature t_{ext}, °C.

The electric heater works when the outdoor unit goes into defrost mode. In addition, it automatically turns on when $t_{ext} < -15$°C. The latter guarantees more reliable operation of the system under these conditions.

The work of a heat pump with low-temperature heating systems is promising and effective [20–21].

During operation of the heat pump on the «warm floor», the temperature of the heat carrier in the area of permanent presence of people should not exceed + 30°C. Such an output temperature significantly increases the efficiency of using a heat pump.

The choice of heating system has a greater influence on the efficiency of the heat pump than the outside air temperature. At a negative temperature t_{ext}, °C, the use of a heat pump with high-temperature heating systems is ineffective. On the other hand, when replacing traditional heating systems with low-temperature ones, the efficiency of heat pumps increases dramatically. Therefore, this factor must be taken into account when designing heating systems using a heat pump [22].

Energy can constantly move without limitation from the device, where it is selected, to heating radiators, so this process resembles the method of pumping any liquid or gaseous substances. Despite the fact that the heat pump used to heat the house consumes a significant amount of electricity, as a result, this method of heating will be much cheaper than using traditional furnaces and boilers.

Due to the constant increase in electricity and natural gas prices due to the high coefficient COP, the use of heat pumps will lead to higher energy efficiency compared to traditional heating systems. When using heat pumps, it is important to reduce energy losses in the machines themselves, as this significantly increases the conversion factor [23].

The power of heat pumps, presented on the domestic market, is currently quite diverse, which makes it possible to provide heating for a private house. The main priority in the implementation of such a project is the availability of a source of low-temperature thermal energy and the economic efficiency of the project itself. Before installing a heating system, there is a need for a heating project, as well as a preliminary calculation of heat losses in the room – this is necessary in order to choose the most efficient pump that will supply heat in the required amount.

The use of heat pumps is economically justified if the heat energy is used directly at the place of installation of the equipment. In heat supply systems for private houses, it is necessary to take into account the length of the consumer's heat networks, which require capital investments during construction and operation, but in the long term pay for themselves in 4–5 years of use.

Conclusions. The use of heat pumps is economically justified if the heat energy is used directly at the place of installation of the equipment. High capital investment at the initial stage of use holds back the widespread implementation of installations. Currently, most manufacturers are already working on making the technology cheaper, so the prospects for using heat pumps in heat supply systems of private houses are quite optimistic.

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ДОСЛІДЖЕННЯ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ ТЕПЛОВОГО НАСОСУ В СИСТЕМІ ТЕПЛОПОСТАЧАННЯ ПРИВАТНОГО БУДИНКУ

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Резюме. *На даний час попитом користуються теплові насоси, які завдяки високому коефіцієнту перетворення теплоти зменшують енергоспоживання та негативний вплив на навколишнє середовище. Перевагами використання теплового насоса є безпечність, екологічність, економічність і те, що при його* *використанні зменшується залежність від зростання цін на природні енергоносії. Однією з головних проблем повітряного теплового насоса є зменшення продуктивності при зниженні температури зовнішнього повітря в зимовий період. Енергія здатна без обмеження постійно переміщатися від пристрою, де здійснюється її відбір, до радіаторів опалення, тому цей процес нагадує спосіб перекачування будь-яких рідких або газоподібних речовин. Навіть незважаючи на те, що тепловий насос, який використовується для опалення будинку, споживає значну кількість електроенергії. В результаті такий спосіб обігріву обійдеться значно дешевше за використання традиційних печей і котлів. Проаналізовано роботу теплового насосу типу повітря-вода: Mitsubishi Electric PUHZ-SHW230YKAR1 для забезпечення приватного будинку опаленням, гарячим водопостачанням та кондиціонуванням повітря. Експеримент довів, що при збільшенні температури теплоносія на виході вище 50°C якісні характеристики теплового насосу не збільшуються. Таким чином, високі технічні характеристики обладнання не завжди виправдані експериментальним шляхом. Проте дослідження обладнання, яке завозять в Україну, слід робити, щоб розуміти, на що можна розраховувати споживачу. Застосування теплових насосів є економічно виправданим, якщо теплова енергія використовується безпосередньо на місці установки обладнання. Високі капіталовкладення на початковому етапі використання утримує повсюдне впровадження установок. Наразі більшість виробників вже працюють над здешевленням технології, тому перспективи використання теплових насосів у системах теплопостачання приватних будинків досить оптимістичні.*

Ключові слова: *тепловий насос, енергозбереження, теплоносій, кондиціонування повітря, гаряче водопостачання, енергоефективність, теплова продуктивність, споживана потужність, спліт – система.*

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