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INFLUENCE OF CHANGING CLIMATIC CONDITIONS ON HEAT PUMP EFFICIENCY

Abstract: *The analysis of energetic and economic efficiency of application of heat supply systems on the basis of brine heat pumps of different types for a covering of heating loading is carried out. The influence of bivalent temperature on the power choice of the heat pump system is shown.*

Keywords: *heat pump, bivalent temperature, heat load, additional source.*

Introduction

Reserves of traditional hydrocarbons such as gas, oil, coal are declining every year. And their use is associated with a negative impact on the environment.

Today, there is a need to move to greater use of renewable energy sources, which are inexhaustible and can guarantee energy and environmental security.

Among renewable energy sources, the use of low-potential environmental energy, converted to high-potential using heat pumps (HP), is promising.

Experience shows that HP is one of the promising types of equipment for creating heat and cold supply systems.

Currently, in some countries, the level of development of this method of heat supply is such that HPs are intensively displacing traditional methods based on the direct combustion of fossil fuels.

The source of heat for the heat pump used in the heat supply system can be water, soil and air, wastewater, ventilation air, and other heat carriers, the temperature of which is 4-12°C.

In the case of widespread implementation of heat pumps, emissions of CO_2 and carcinogenic compounds formed during the combustion of minerals are also significantly reduced.

According to [1] HPs are used for buildings of energy efficiency of class C and above. When using HP in the heating system, the most common is the bivalent scheme, when HP provides most of the heat load for heating the building, and the rest is covered by an additional source: electric, gas, or solid fuel boiler. To determine the power of the HP it is necessary to know the bivalent temperature at which the additional source is connected. The bivalent temperature is influenced by many factors: the type of HP, weather conditions (ambient air temperature and duration of their standing).

The value of the bivalent temperature affects the share of heat load that covers the HP, so studies aimed at determining the bivalent temperature depending on the ambient temperature are relevant.

The goal of this paper is to analyze the influence of ambient air temperature on the temperature of bivalent HP in the heating system and determine the proportion of coverage of the heat load by the heat pump.

The object of the study was an individual residential building with a heating area of 1500 m² with a thermal load on the heating system of 100 kW, which is located in Kyiv.

Presentation of the main research material

Climatic conditions of Kyiv are characterized by a short time of low ambient temperatures during the heating period. This is the reason when choosing a heat pump not to choose it at maximum power.

The paper considers a bivalent scheme of heat supply of the house when the heat load is distributed between the heat pump and an additional peak electric heater, which is connected only when the outside air temperature is below the bivalent.

The heating system has a battery tank with a built-in electric heater.

To determine the influence of ambient temperature on the value of bivalence temperature and HP power, statistical data on the duration of the standing ambient temperatures in the heating seasons during the 2015-2020 years for the city of Kyiv (Table 1) was collected.

TABLE 1. *The number of hours of ambient temperatures in different heating seasons*

Ambient temperature, °C	Heating power, kW	A number of hours of standing temperatures, h					
		St. year	15-16	16-17	17-18	18-19	19-20
8	29	654	864	732	531	645	831
5	36	1480	1797	1590	1632	1323	1824
0	48	1225	711	1206	1188	1245	738
-5	60	627	105	201	171	324	48
-7	64	336	189	261	243	231	48
-10	71	130	129	159	201	81	0
-15	83	31	63	54	12	0	0
-20	95	5	0	0	0	0	0
-22	100	0	0	0	0	0	0
Average temperature heating season, °C		0.77	3.78	2.16	2.63	2.93	5.43
Number of heating hours, h		4488	3858	4203	3978	3849	3489
Heating load, MWh		230.6	175.4	201.6	176.3	169.5	145.1

Based on the obtained data, an integrated graph of the dependence of the coverage of the heated load on the capacity of the heating system for the specified period was constructed (Fig. 1).

Figure 2 shows the effect of outdoor air temperature during the heating period on the power of the heat pump.

The graph (Fig. 2) shows that the increase in outdoor temperature during the heating period shifts the bivalence point towards higher temperatures (decreases the power of the HP and increases the load factor).

For a given building, it is proposed to use HP with a capacity of 60 kW to 70 kW, which will depend on the type of HP and the manufacturer. The bivalent temperature will vary from minus 5°C to minus 9.4°C with coverage of 97-99% of the heat load.

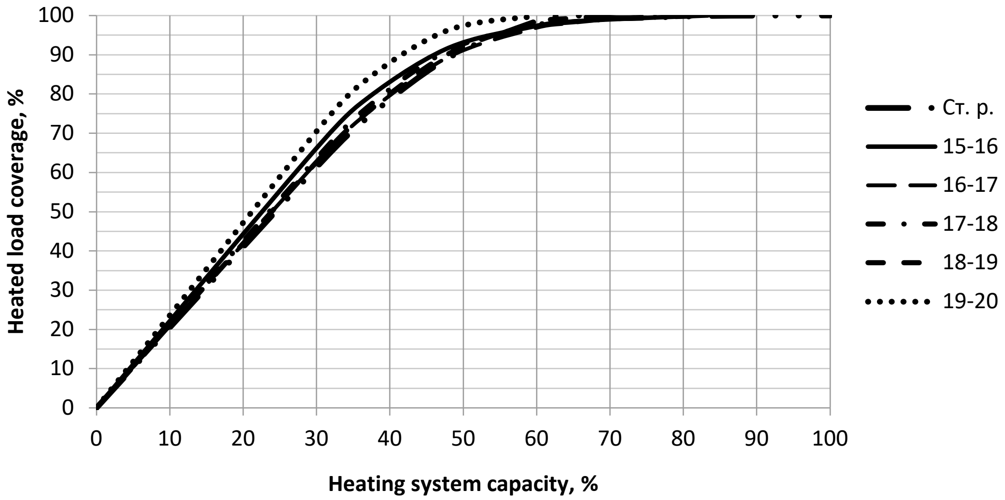

FIGURE 1. Dependence of the heat load coverage factor on the capacity of the heating system in the heating seasons during 2015-2020 for the city of Kyiv

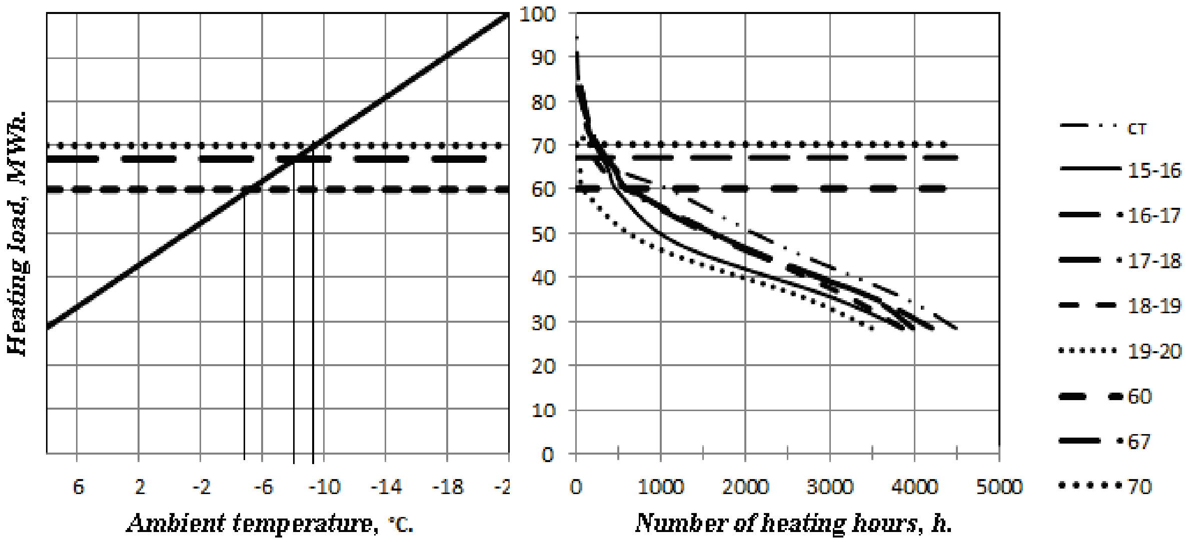

FIGURE 2. Determination of the bivalence point

During the day, the outside air temperature may drop below minus 8°C, but the use of the accumulator tank (AT) in the heating system, external insulation of the building walls (a brick wall cools 6 times slower [1]), and allowance of reduction the heating temperature at night by 3°C [2] reduces energy consumption by an additional heat source, and HP will work with less load.

To analyze the energy consumption of an additional heat source, statistical information about the average daily temperatures below minus 8°C for a certain period was analyzed.

The value of the average daily temperatures below minus 8°C is shown in Table 2.

Table 3 shows the values of the amount of heat from an additional source with and without AT. Using a battery tank saves 13-58% of heat from an additional source.

TABLE 2. The value of average daily temperatures below minus 8 ℃

Heating seasons	December		January		February	
	days months	variations t_3, °C	days months	variation t_3, °C	days months	variation t_3, °C
15-16	30-31	-8.2…-9.2	1-6; 18-25	-8.2…-16.5 -8.2…-9	–	
16-17	7	-8	6-9; 26; 30-31	(-9.1)-(-16.5); -9.7; -8.2…-12.4	1; 7-10	-9.1; -9.3…-17.2
17-18	–		14-16; 23-26	-8.2…-10; -8.6…-9.3	24-28	-8.4…-13
18-19	–		8-11 25	-8.1…-11; -10.7	–	
19-20	–		–	–	–	

TABLE 3. The amount of heat from the additional source

Month	Heating seasons				
	15-16	16-17	17-18	18-19	19-20
The heat from an additional source of AT, kWh	2584	2600	1351	545	–
The heat from an additional source without AT, kWh	2985	3235	2695	1298	79

Tables 1-3 show that the coldest heating season is 2016-2017, and the warmest is 2019-2020.

The use of underfloor heating with a coolant temperature of 35°C increases SCOP and reduces electricity consumption by up to 19%.

The bivalent temperature depends on the power of the HP and does not always correspond to its optimal value.

To determine the efficiency of different types of HP, several variants with a capacity of 60-70 kW were selected to cover the heat load (heating) of different manufacturers. Depending on the type and amount of HP [3, 4], the power of the main source of the heating system and, accordingly, the bivalence point and the amount of heat from the additional source change (Table 4).

TABLE 4. Characteristics of HP

Brand	Power, kW	COP	Number, pcs.	General power, kW	Point bivalence	Price, $
HeatHouse-Geo18	17.2	4.59	4	68.8	-8.9	25628
AIK MINI PRO20	20	4.22	3	60.0	-5.2	19572
Vaillant flexoTHERM exclusive VWF 197	19.7	4.7	3	59.1	-4.8	31587
HP20S25W-M-BC	20.1	4.9	3	60.3	-5.3	38700
IDM SW 17 COMPLETE	17.18	4.71	4	68.7	-8.86	51208
DeWix DW20000	21.11	4.31	3	63.3	-6.6	21000
NIBE F1345	67	3.8	1	67	-8.14	24400

The results of calculations of the influence of the bivalent point on heat production by different energy sources (external environment – Q_{EE}, compressor – Q_{C}, additional source – Q_{AC}) in the coldest heating season (2016-2017) and the warmest (2019-2020) shown in Figure 3.

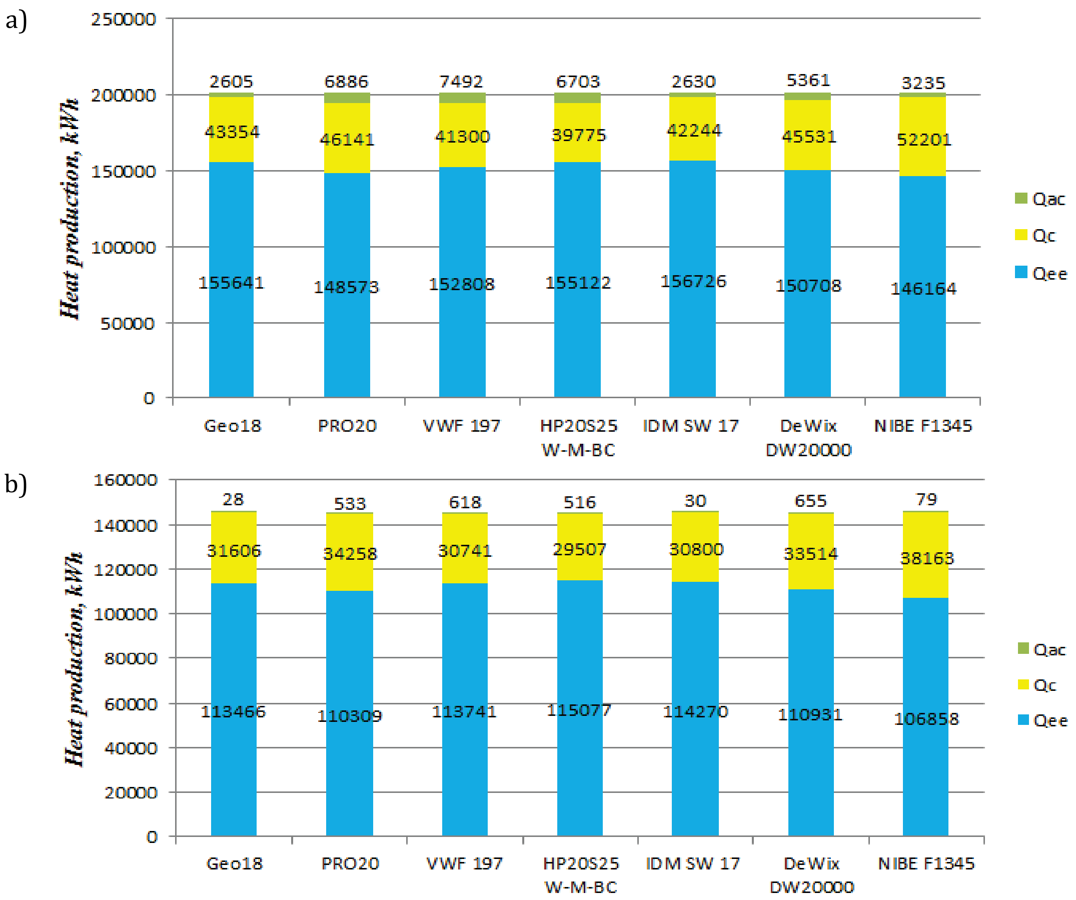

FIGURE 3. *The amount of heat received from different energy sources in the heating system in the heating seasons: a) 2016-2017; b) 2019-2020*

Depending on the amount of heat spent on heating, the payback period of the HP system will change (Table 5). To determine the annual savings from the installation of HP it was compared with a gas boiler (boiler efficiency 95%) to determine the cost of fuel used [5].

TABLE 5. *Payback period of the heating system with different HP*

Brand	Heating season					
	16-17			19-20		
	Electricity costs, UAH	Savings, UAH	Payback term, year	Electricity costs, UAH	Savings, UAH	Payback term, year
Geo18	77211	96208	7.3	53145	71672	9.8
AIK MINI PRO20	89085	84334	6.4	58448	66369	8.1
VWF 197	81970	91450	9.5	52683	72134	12.0
HP20S25 W-M-BC	78083	95336	11.2	50439	74379	14.3
IDM SW 17	75389	98031	14.4	51795	73022	19.3
DeWix DW20000	85499	87921	6.6	57404	67413	8.6
NIBE F1345	93133	80286	8.4	64247	60570	11.1

From Table 5 it follows that the shortest payback period of 8.1 years has a HP of AIK MINI PRO20 company with a total capacity of 60 kW and a bivalent point of -5.2°C. Although, the cost of electricity (compressor drive and water heating in the additional source) is higher compared to other HP due to the lower SCOP.

An increase in the bivalent temperature leads to an increase in the payback period of the heating system with a heat pump. This is due to the fact that the most significant factor in the calculation is energy consumption, which affects the profitability of the heating system, and the price of HP.

When determining the optimal heating system, it is necessary to take into account the point of bivalence and the payback period of HP.

Conclusions

The analysis was performed of statistical data on changes in outdoor air temperature during the heating season for the period 2015-2020 for the city of Kyiv. The coldest heating season is 2016-2017, and the warmest is 2019-2020. The heat load of the building heating system varies from 145.1 MWh to 201.6 MWh depending on the season.

When the bivalence temperature changes from minus 4.8°C to minus 8.9°C, the power of the HP changes from 59.1 kW to 68.8 kW. Accordingly, the amount of heat from the main source changes 194-199 MWh in the coldest heating season and 144-145 MWh in the warmest. The heat from the additional source is 2605 – 7492 kWh, 28 – 655 kWh respectively.

The payback period ranges from 6.4 years to 19.3 years, depending on the heat consumed during the heating season and the type of HP.

Comparison of heat supply systems with different HP allowed to choose the most optimal option to cover the heating load of a given building – HP AIK MINI PRO20.

Conflicts of Interest: The author declares no conflict of interest.

Reference

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