ENERGETICS

ЕНЕРГЕТИКА

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APPLICATION OF CAD TECHNOLOGIES FOR RESEARCH OF HEAT EXCHANGE UNITS OF MICROCLIMATE SYSTEMS BASED ON ALTERNATIVE ENERGY SOURCES

О.А. Климчук, Г.В. Лужанська, Г.А. Баласанян М.І. Сергеєв, І.М. Аксьонова. **Застосування САПР технологій у дослідженні теплообмінних установок систем мікроклімату на основі альтернативних джерел енергії.** Економія паливно-енергетичних ресурсів нині стає одним із найважливіших напрямів переведення економіки України на шлях інтенсивного розвитку та раціонального природокористування. Актуальним напрямком у розвитку сучасної енергетики є розвиток екологічно чистої енергетики на основі альтернативних джерел енергії з метою енергопостачання. Одним з шляхів вирішення цієї задачі є використання у системах мікроклімату приміщень різного призначення комбінованої системи теплопостачання, до складу якої входить декілька джерел теплової енергії (традиційних або відновлюваних), призначення її компенсація тепловтрат через зовнішні огороджувальні конструкції, забезпечення роботи систем припливно-витяжної вентиляції та гарячого водопостачання споживачів. Для узгодження режимів генерації та споживання теплоти застосовано акумулювання енергії. Для різних схем підключення генераторів теплоти та споживачів проведено дослідження ефективності використання об'єму акумулятора. За допомогою системи автоматизованого проектування розроблено метод ефективної роботи теплового акумулятора, при дослідженні динаміки нагріву теплоносія в баку акумулятора теплоти при різних схемах підключення. В результаті виконаних досліджень теплообмінної установки за допомогою спеціалізованого програмного комплексу отримано, що при перехресному підключені генератора та споживача теплоти до баку акумулятора, середня температура теплообмінного акумулюючого матеріалу практично співпадає із температурою зворотної магістралі, що свідчить про більш рівномірне поле температур в об'ємі теплового акумулятора. При цьому, при зарядці та розрядці акумулятора теплоти спостерігається повний збіг графіків зміни температури для обох періодів.

Ключові слова: теплообмінні установки, теплові акумулятори, альтернативні джерела енергії, системи мікроклімату, відновлювальні джерела енергії

O. Klymchuk, G. Luzhanska, G. Balasanian, M. Serheiev, I. Aksyonova. **Application of CAD technologies for research of heat exchange units of microclimate systems based on alternative energy sources**. Saving fuel and energy resources is now becoming one of the most important areas of transition of Ukraine's economy to the path of intensive development and rational use of nature. An important direction in the development of modern energy is the development of clean energy based on alternative energy sources for energy supply. One of the ways to solve this problem is to use in microclimate systems for various purposes combined heat supply system, which includes several sources of heat (traditional or renewable), its purpose – to compensate for heat loss through external enclosing structures, supply and exhaust ventilation systems and hot water supply to consumers. Energy accumulation was used to coordinate the modes of heat generation and consumption. A study of the efficiency of battery capacity has been conducted for various connection schemes of heat generators and consumers. With the help of the automated design system the method of efficient operation of the heat accumulator is developed, at research of dynamics of heating of the heat carrier in a tank of the heat accumulator at various schemes of connection. As a result of researches of heat exchange installation by means of the specialized software complex it is received that at cross connection of the generator and the consumer of heat to the accumulator tank, average temperature of heat exchange accumulating material practically coincides with temperature of the return highway that testifies to more uniform temperature field in heat accumulator volume. At the same time, when charging and discharging the heat accumulator, there is a complete coincidence of temperature change graphs for both periods.

Keywords: heat exchange units, heat accumulators, alternative energy sources, microclimate systems, renewable energy sources

Introduction

In the current global energy crisis, the question of efficient use of fuel and energy resources arises. The solution to this problem is the development and implementation of innovative energy efficient systems and technologies.

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Implementing an effective policy will allow Ukraine to create conditions for optimizing the structure of the country's energy balance. According to the Ukraine 2020 Sustainable Development Strategy, the implementation of the Energy Independence Program will be among the top priorities. The main task of the program is to ensure energy security and the transition to energy efficient and energy efficient use and consumption of energy resources with the introduction of innovative technologies [1, 2].

The main objectives of public policy are the transition to the use of energy efficient technologies and equipment, the implementation of projects using alternative energy sources [3].

The scientific program of the Ministry of Education and Science of Ukraine indicates the need to increase the scale of rational use of alternative energy sources for energy supply [4].

Analysis of recent research

Although currently the unit cost of alternative energy is higher than traditional energy generation, competitiveness can be significantly improved using the latest energy-saving and environmentally friendly technologies.

One of the ways to solve this problem is to use in microclimate systems for various purposes combined heat supply system, which includes several sources of thermal energy (traditional or renewable). Its purpose is to compensate for heat loss through external enclosing structures, ensuring the operation of supply and exhaust ventilation systems and hot water supply to consumers [5].

Gas boilers, solid fuel boilers, electric boilers are used as traditional energy sources, and heat pumps and solar systems are preferred as renewable ones [6, 7].

It should be noted that manufacturers of heat and power equipment have developed recommendations for circuit solutions for the use of renewable heat sources, but they are usually aimed at improving the hydraulic performance of traditional and alternative systems, as well as coordination of automation system.

Purpose

The aim of the work is to study the operation of the heat exchange unit for microclimate systems for the introduction of alternative energy sources using CAD tools.

Presenting main material

The efficiency of the boiler room is influenced by the schemes of connecting consumers to heat generators (Fig. 1). Scheme with one circulating pump – individual boilers (Fig. 1, *a*); scheme with distribution manifold and one circulating pump (Fig. 1, *b*); scheme with distribution manifold and individual circulating pumps (Fig. 1, *c*); scheme with the use of a hydraulic distributor (Fig. 1, *d*).

The solution of hydraulic problems of the consumer-boiler system can be solved by using a hydraulic separator (Fig. 1, *d*) or a heat accumulator (buffer tank). With this solution, the boiler produces the required power without changing the flow rate, and consumers receive the required amount of heat with the desired parameters. This scheme has shown in practice the best technical and economic results, namely, reducing fuel consumption and reducing the number of accidents, so that leading manufacturers insist on its practical implementation.

Gas boiler differs favorably from solid fuel boilers by a simplified fuel economy system, low inertia in the automatic control system, as well as a wide range of heat control.

Boilers that use solid fuel for reliable and economical operation require the installation of special buffer tanks (heat accumulators). This measure, in addition to increasing the efficiency of the boiler, is also a safety measure, when reducing the load must be removed from the boiler excess heat.

For the conditions of Ukraine, a rational solution is to use an electric boiler with a heat accumulator, which is charged from 23.00 to 6.00 (at night rate), and during the day the battery is discharged, providing heat to the house.

This system helps to address a number of issues:

– saves on heat supply;

– equalization of the daily schedule of energy consumption of the building;

– reducing the use of traditional fuels.

The heat source in the heat pump unit is a steam compression refrigeration machine with a heat pump function. Fan coils – convectors with a fan and control system are used as heating and cooling devices [7, 8]. This system allows you to integrate other heat sources without changing the internal engineering systems of the building. To coordinate the modes of operation of the heat generation system and consumers, as well as for more uniform thermal operation, such systems must be equipped with heat accumulators (cold).

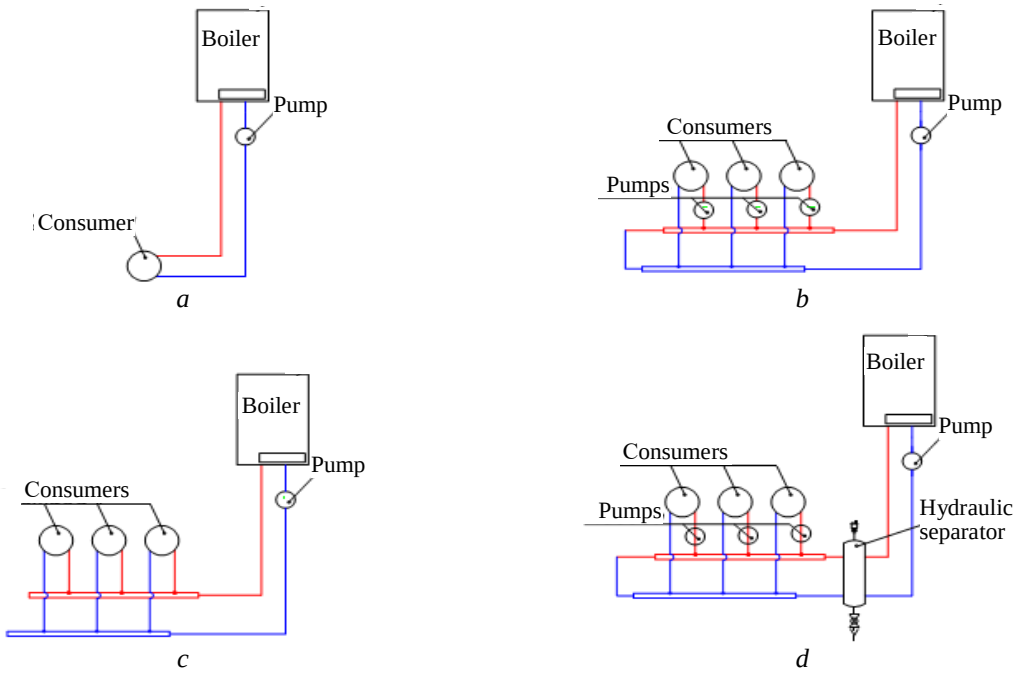

Fig. 1. Schemes of connection of boiler-houses to consumers: *a* – single-circuit connection of the boiler to the consumer; *b* – multi-circuit connection of the boiler to consumers; *c* – multi-circuit connection of the boiler to consumers with separate pumps; *d* – multi-circuit connection of the boiler to consumers with separate pumps and hydraulic separator

Heliosystems are characterized by daily unevenness. Therefore, it is advisable to use heat accumulators, which can be narrow-profile – hot water accumulator-water heater and multi-profile – accumulator tank with a function of wide heat supply [9].

A feature of solar systems is the annual uneven heat productivity of solar collectors. In the cold period of the year at the maximum need for heat productivity of solar collectors is minimum, and in the summer – on the contrary. This leads to a rational approach to calculating the number of modules of solar panels.

For the most efficient use of insolation in an alternative heat supply system resort to annual heat storage [10].

Heat accumulation is the process of heat accumulation during the period of its greatest receipt for subsequent use, when the need arises. The process of energy accumulation is called – *charging***,** the process of its use – *discharge*.

The main such processes include:

– accumulation – the release of internal energy when heating – cooling solid or liquid bodies;

– phase transitions with absorption – release of hidden heat;

– sorption – desorption processes;

– reverse chemical reaction that occurs with the release – heat absorption.

These processes are implemented in heat accumulators.

Heat accumulators are usually used in those areas of the economy where there is an uneven supply of heat energy, and can reduce energy consumption through the use of alternative energy sources, or increase the efficiency of energy equipment [4, 11].

In the range of operating temperatures 0…100 °C water is the best liquid heat-accumulating material [12] both on a complex of thermophysical properties, and on economic indicators.

The use of heat accumulators in combined heat supply systems is presented in the structural and logical diagram (Fig. 2), which shows which factors can significantly affect the efficiency of energy supply and thus increase the share of substitution and achieve a positive environmental effect.

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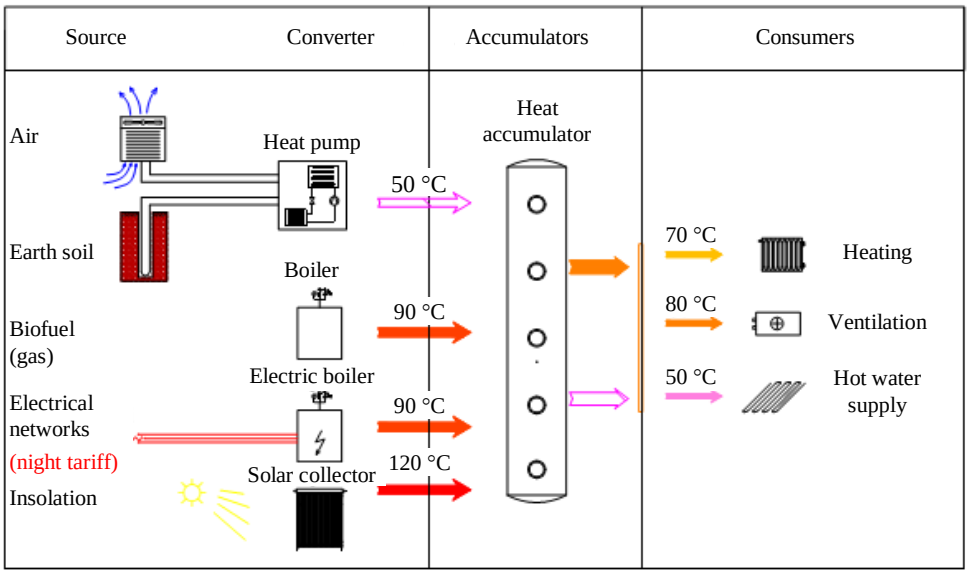


Fig. 2. Structural and logical scheme of microclimate systemswith heat accumulator

As can be seen from the diagram, the greatest effect from the use of different energy sources and the connection of different potential consumers can be achieved through the correct redistribution of heat when connected to the battery tank.

There are three means of connecting heat exchangers relative to the movement of coolant flows: parallel, cross, compatible.

Results

We will study the operation of the heat accumulator using a specialized system complex that is a powerful tool for 3D modeling and automated design of complex products for various purposes, which allows you to conduct virtual technical tests and research on the model. The mathematical basis of the complex is the method of finite volumes [4, 13, 14].

To perform time sampling, for each cell of the calculation grid in the calculation area under the Courant condition, the allowable maximum time step is determined, which depends on both the values of physical quantities and the space sampling step in this cell. If a nonstationary problem is solved, then the minimum of the time steps defined in this way is determined for all cells of the calculation grid in the calculation area. With this step, the same for all cells, the transition is performed (ie, the calculation of parameters) to the next point in time.

As a result, to calculate the values of the flow parameters on the next time layer $(n+1)$ from the known values of these parameters on the previous time layer (n), the following system of algebraic equations is used:

$$\frac{U^* - U^n}{\Delta t} + A_h(U^n, p^n)U^* = S^n, \tag{1}$$

$$L_h \cdot \delta p = \frac{\mathrm{div}_h(\rho u)}{\Delta t} + \frac{1}{\Delta t} \cdot \frac{\rho^* - \rho^n}{\Delta t}, \tag{2}$$

$$\rho^* = f(p^n + \delta p, T^*, y^*), \tag{3}$$

$$(\rho u)^{n+1} = (\rho u)^* - \Delta t \cdot \mathrm{grad}_h \cdot \delta p, \tag{4}$$

$$P^{n+1} = p^n + \delta p, \tag{5}$$

$$(\rho T)^{n+1} = (\rho T)^*;\ (\rho k)^{n+1} = (\rho k)^*;\ (\rho \varepsilon)^{n+1} = (\rho \varepsilon)^*;\ (\rho y)^{n+1} = (\rho y)^*, \tag{6}$$

$$p^{n+1} = f(p^{n+1}, T^{n+1}, y^{n+1}), \tag{7}$$

where U^* – vector of all independent variables except pressure;

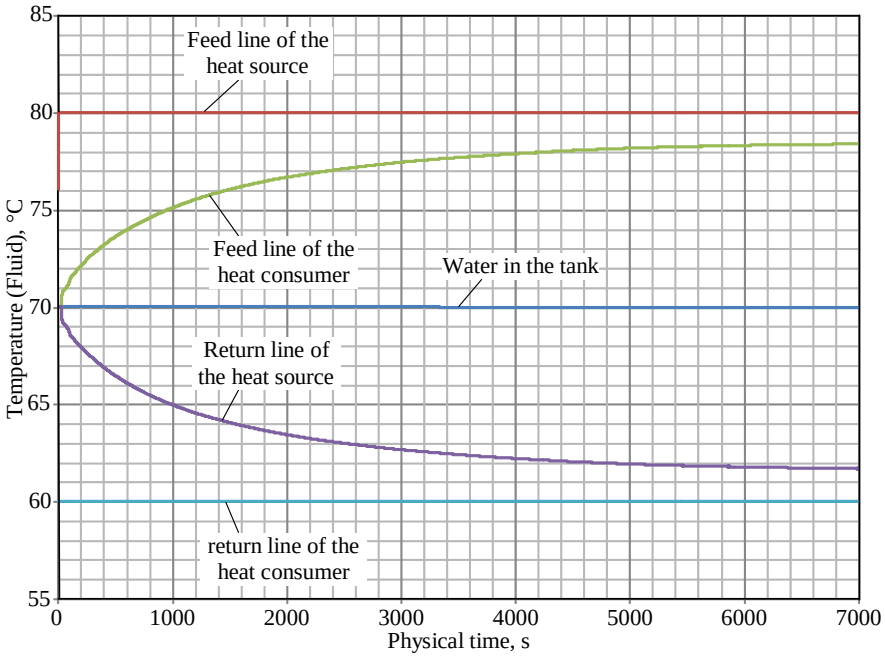
u – speed vector;

$y = (y_1, y_2, \ldots, y_n)$ – vector of concentrations of fluid components;

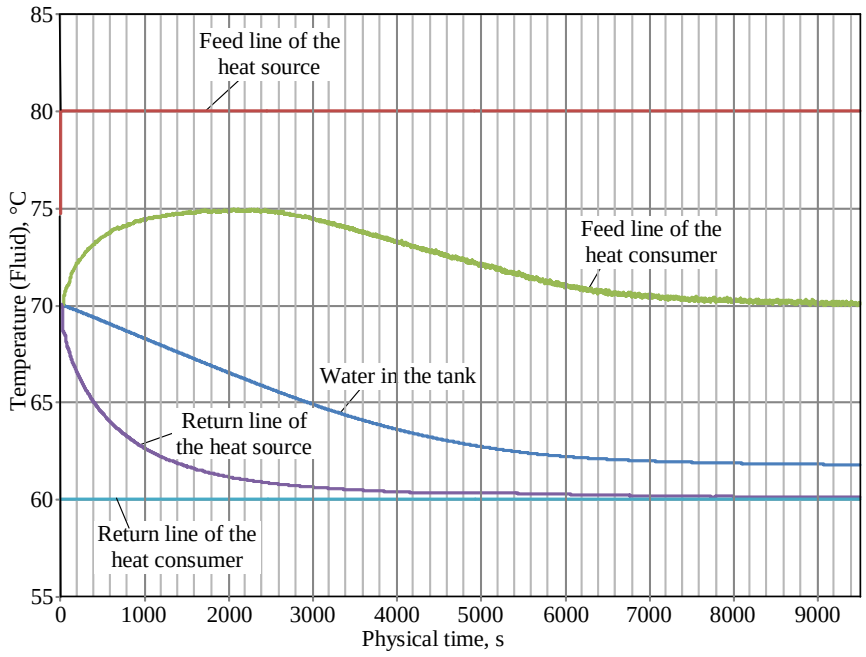
p^{n+1} – auxiliary variable, pressure correction.

The index "*" indicates the intermediate (between layers n and $n + 1$) values of variables. All values of variables refer to the centers of computing cells. Discrete operators A_h, div_h, grad_h and $L_h = \mathrm{div}_h \mathrm{grad}_h$ approximate the corresponding differential operators with the second order of accuracy.

Graphic dependences are constructed according to the results of researches of effective work of heat exchange installation. Figures 3, 4 show the dynamics of heating the coolant in the heat accumulator tank with parallel and cross connection schemes at the end of the charging and discharging processes.



a



b

Fig. 3. Dynamics of heating the coolant in the heat accumulator tank with parallel connection schemes: *a* – at the end of the charging); *b* – at the end of discharging

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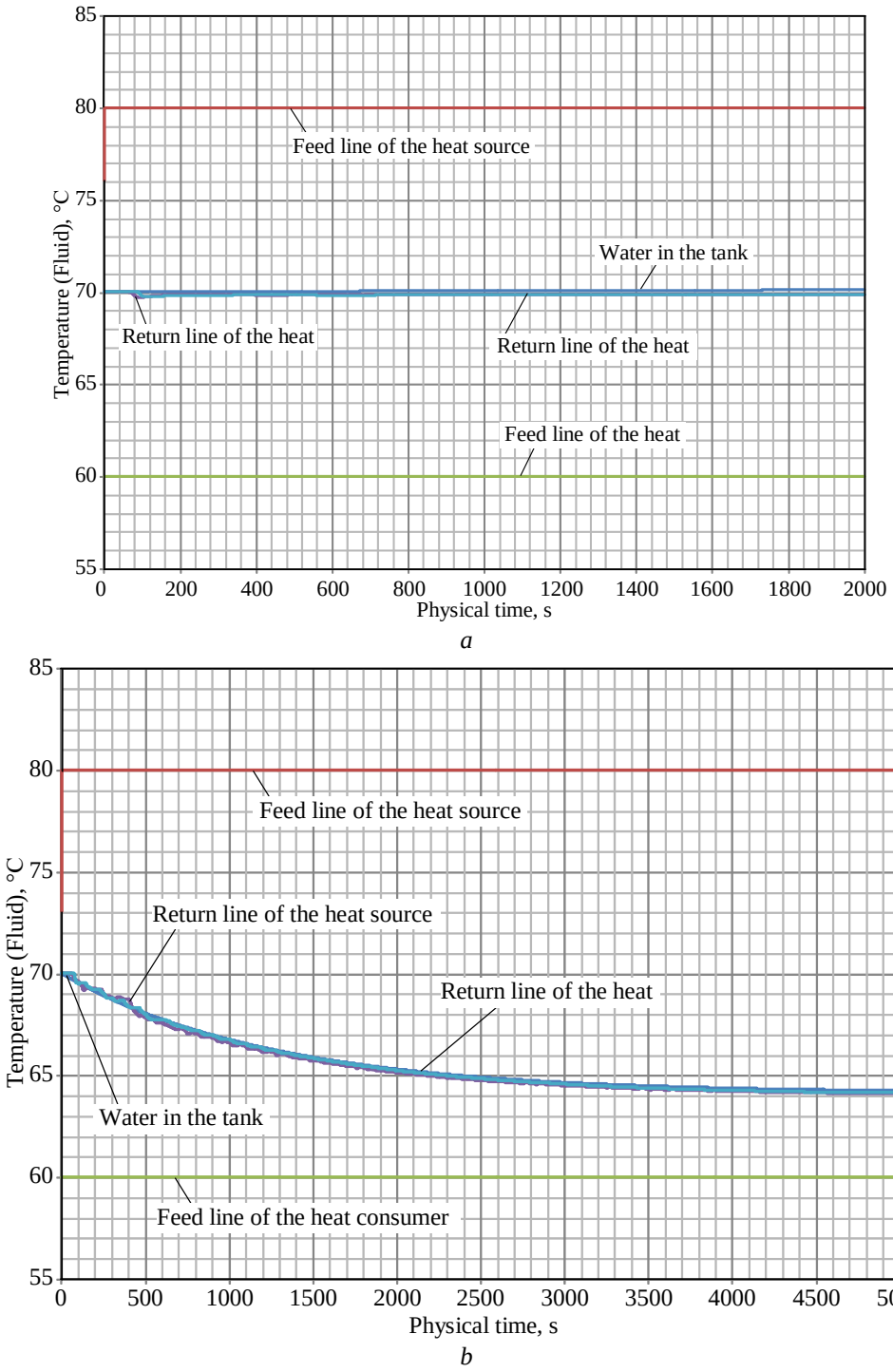

Fig. 4. Dynamics of heating the coolant in the heat accumulator tank with cross connection schemes: *a* – at the end of the charging; *b* – at the end of discharging

Analyzing the results of the study of the battery tank, which is connected to different circuits of the coolant (parallel and cross), it should be noted that the greatest efficiency can be achieved using cross-version, as the charging and discharging process compared to the analyzed tools in this case increases.

Conclusions

1. Taking into account the peculiarities of climatic conditions, the most promising for Ukraine is the introduction of integrated systems of alternative combined heat supply. Namely:

– energy potential of alternative energy sources (insolation, ambient heat, etc.) based on the heat pump cycle;

– technical potential of various devices for heat storage, including with the possibility of energy storage at the night rate;

– dynamic capabilities of the heating system, including the ability of the system to forced space heating;

– backup heat generators, including on alternative fuels, which is an efficient way to save energy.

The efficiency of combined use of alternative and traditional heat sources in the microclimate systems of premises and buildings for different purposes depends on the technical characteristics of the equipment used.

The use of heat accumulators can increase the efficiency of microclimate systems where there is an uneven supply of thermal energy and reduces energy costs using alternative energy sources.

2. As a result of studies of the heat exchange unit using SolidWorks software, it was found that when the generator and heat consumer are cross-connected to the battery tank, the average temperature of the heat exchange storage material almost coincides with the return temperature, which indicates a more uniform temperature field heat accumulator capacity. At the same time, when charging and discharging the heat accumulator, there is a complete coincidence of temperature change graphs for both periods.

The duration of the process of charging and discharging the battery increases compared to the traditional (parallel) connection of the generator and the consumer, which indicates a more efficient use of battery capacity with a cross-circuit.

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