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LATENT HEAT ENERGY STORAGE DEVICE AS A PART OF THE VENTILATION SYSTEM OF INDIVIDUAL HOUSE

Energy efficient ventilation systems allow to minimize the heat energy consumption for heating supply air, which is very relevant in the context of rising energy prices. It is dealt with the variant of the installation seasonal phase-change heat storage device in the system of ventilation with recuperation of heat energy. Preliminary engineering calculations were perfomed and the quantity of heat storage material (water) necessary for the operation of the ventilation system was determined. The diagrams of change the temperature of the air at the output from the accumulator and distribution of water and ice during the heating period were given. In the article the calculation of seasonal heat storage device on the basis of the water in the supply air ventilation systems are considered , which allows to minimize costs of thermal energy for heating the outside air before it enters to the premises of the house. It is proved that in modern economy conditions development the energy-efficient ventilation system is a promising direction of research and implementations.
Keywords: *heat storage device, heat recovery, individual house.*

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ТЕПЛОАКУМУЛЯТОР ФАЗОВОГО ПЕРЕХОДУ У СКЛАДІ СИСТЕМИ ВЕНТИЛЯЦІЇ ІНДИВІДУАЛЬНОГО БУДИНКУ

Визначено, що енергоефективні системи вентиляції дозволяють звести до мінімуму споживання теплової енергії для нагріву припливного повітря, що є досить актуальним в умовах зростання цін на енергоресурси. Досліджено варіант установлення сезонного теплового акумулятора в систему припливної вентиляції з рекуперацією теплової енергії. Наведено графіки кількості теплоти, необхідної для роботи системи вентиляції, діаграми зміни температури повітря на виході з акумулятора й розподілу води та льоду протягом опалювального періоду. Розглянуто розрахунок сезонного теплового акумулятора фазового переходу на основі води у складі припливної вентиляційної системи з рекуперацією теплоти, що дозволяє звести до мінімуму витрати теплової енергії для нагріву зовнішнього повітря перед подачею у приміщення житлового будинку. Доведено, що в умовах сучасної економіки розроблення енергоефективної вентиляційної системи є перспективним напрямком досліджень.
Ключові слова: *тепловий акумулятор, рекуперація тепла, житловий будинок.*

Introduction. The rise of fuel and energy price is the most important stimulus of their economy, but any transition to energy-saving technologies will require additional investment and material costs. The rising cost of fuel and energy production contributes to inflationary processes, affects to the size and structure of non-productive consumption. The total impact of the rise in price of energy on the macroeconomic indicators is difficult to quantify [1].

In modern construction, especially in design of the building envelope with big thermal resistance, installation of the modern plastic windows, the main share of the heat load of the buildingis is accounted for the ventilation system. That is why in the current economic conditions with the rising cost of energy development of energy-efficient ventilation system is a promising direction of research and implementations.

In well heat insulated houses, ventilation systems use about 50 – 60 percent of heat. The use of the various designs of the air-to-air heat recovery unit allows to reduce ventilation load by 25 – 30 percents, but with the increase their coefficient of efficiency acute a problem of condensation and icing in this type of heat exchangers.

In the face of rising prices on different types of fuel and the government's commitment to energy independence there is need to develop new technologies which use alternative energy sources. In parallel with these questions arises the problem of efficient use and storage received energy, especially from the air.

Analysis of the latest sources of research and publications. The main task, structure and classification of a variety type of heat accumulators are considered[2, 3]. When using the latent heat of some substances the process of accumulation characterized by a high density of energy stored, small changes in temperature and stable temperature at the outlet of the heat accumulator. Such constructions of the phase change heat storage device are shown (PCHSD) (see Fig. 2) [4, 5].

The selection of not resolved before part of the general problem. There is a significant number of scientific papers devoted to the use of phase-change heat storage device on the basis of paraffin or hydrates, which reduce heat consumption by hot water systems and heating[6, 7, 8], but it should considerd very substantial part of the heat load of the building is the ventilation system. The article describes the calculation of the seasonal type heat storage device, which installed as part of the supply ventilation system with energy recuperation. This engineering solution allows to minimize costs of thermal energy for heating the outside air before it enters to the premises of the house.

Statement of the problem. The main aim of this work is preliminary monthly calculation of the seasonal type phase change heat storage device which isinstalled as part of ventilation system of the individual house, made on the basis of mathematical model of heat balance of water, air and ice.

Main material and results. Heat accumulators can perform the following tasks: compensation of the thermal energy consumption peaks; alignment (optimization) schedules of the thermal energy production by storing excess energy; accumulation of thermal energy, which will be used during the trip (lack of) energy supply.

Any heat storage device consists of: heat-accumulating material (HAM); thermal insulated storage tank to store HAM; systems for charging and discharging; auxiliary equipment.

The heat accumulators are distinguished:

1) the nature of HAM: thermochemical heat storage based on the allocation or absorption of heat in reversible chemical and photochemical reactions; heat accumulators which uses the heat capacity of the heat storage material without changing the state of aggregation; heat accumulators basis on phase transition, which use the latent heat of fusion of the substance;

2) the period of charging and discharging: short-term (up to three days); medium-term (up to one month); long-term heat accumulators;

3) the operating temperature: low temperature (100 °C); medium temperature (100 to 400 °C); high temperature heat storage (400 °C).

A wide range of substances exist, providing accumulation temperature from 0 to 1400 °C. It should be noted that the wide use of phase change heat storage device is constrained primarily by considerations of cost-create installations.

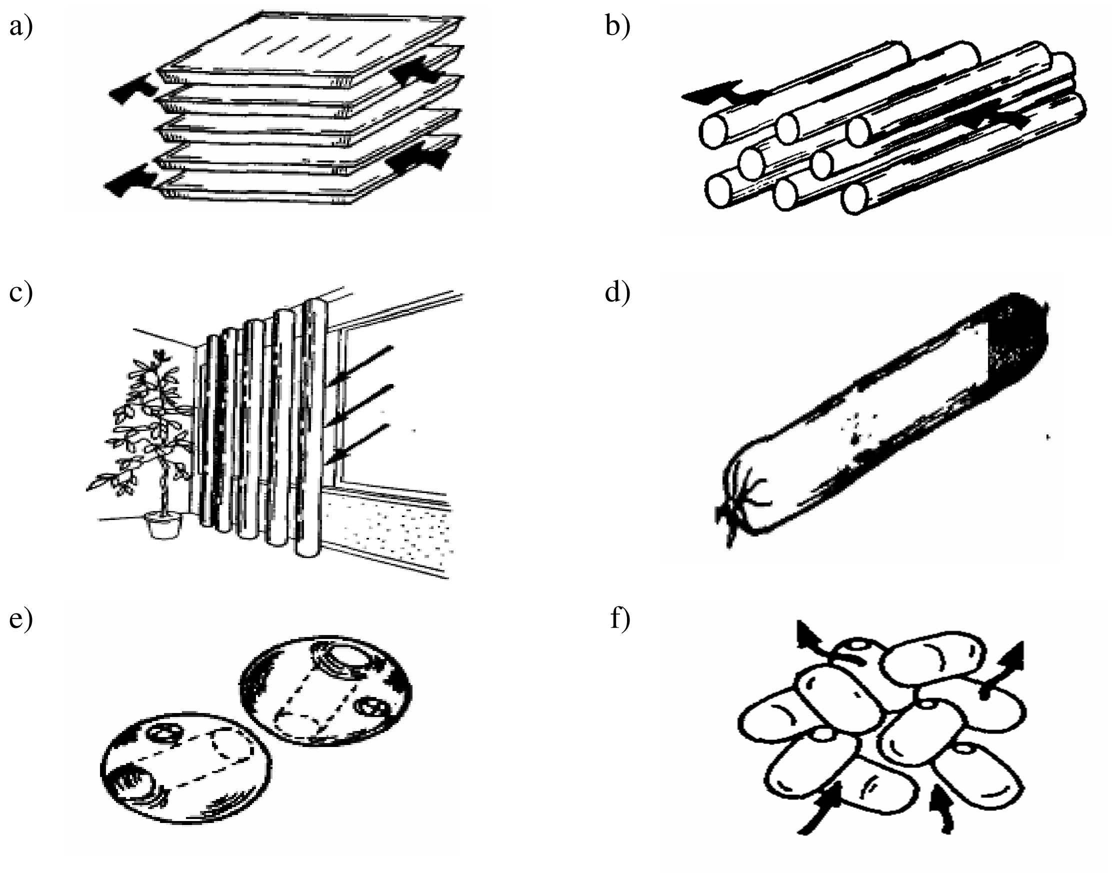

Figure 1 – Main type of the phase change heat storage device:
a – panel; b – pacilic; c – polyethylene pipe which used in passive system of use solar energy; d – pipe; e – balls with through channels for air; f – capsules

When using a thermal effect that arises as a result of the heating and cooling of water or gravel, the quantity of heat produced is small comparated to with the size of the heat accumulator. A disadvantage of this type of heat storage is that it requires significant space and in the process of heat transfer the temperature of the accumulator is reduced. At phase transformations (melting, evaporation and crystallization) allocated the so-called latent heat of phase change, and the quantity of generated heat can be quite significant. If, for example, take water, to obtain 1 kg of water from ice we need 336 kJ/kg and to evaporate 1 kg of water necessarily already 2268 kJ/kg. In the process of evaporation has significantly more heat, but there are significant changes in the volume of the HAM, so the process is advantageously carried out in the heat storage device. Therefore, it is possible to use only the latent heat of melting [4, 9].

Mathematical model to calculate PCHSD will consist of stationary equations of heat balance of air, water and ice under the condition of equality of the final temperature of air and water.

$$\begin{cases} c_{air} \cdot G_{air} \cdot (t_{air}^{in} - t_{air}^{out}) = c_w \cdot G_w \cdot (t_w^{in} - t_w^{out}) \\ c_{air} \cdot G_{air} \cdot (t_{air}^{in} - t_{p.c.}) = r \cdot m_{ice} \end{cases}, \quad (1)$$

where c_{air}, c_w – specific heat respectively for air and water, kJ/kg·K;

G_{air} – mass flow rate of the air supplied to regenerator, kg/h;

t_{air}^{in} – initial air temperature at the inlet to the heat storage device (assumed to be the average monthly temperature t_m, K);

t_{air}^{out} – final temperature of air at the outlet of the thermal battery, K;

$t_{p.c.}$ – phase change temperature of the heat-accumulating material, K;

t_w^{in}, t_w^{out} – respectively the initial and final temperatures of HAM (water), K;

m_w, m_{ice} – mass of water and ice, kg;

r – latent heat of crystallization, for water is 336 kJ/kg.

The use of energy-efficient ventilation system with series connection of the PCHSD and plate heat exchanger is considered on the example of an individual house with total living area of 100 m^2.

The total air flow rate for individual house is:

$$L_{tot} = L_{room} + L_k + L_b, \quad (2)$$

where $L_{room} = F \cdot K$;

F – living room area, m^2;

K – air changes per hour, 1/hour.

L_k, L_b – values of air flow rate, respectively, for living rooms, kitchens and bathrooms, taken in accordance with the norms [10], m^3;

The working time of ventilation system is 720 hours in a month. The design air temperature in the living room is +18°C. The supply air temperature can be reduced on 3°C from given that the room air distribution is carried out through the grille, located under the room ceiling. Total air flow rate for the house is equal L_{tot} = 100 + 90 + 50 = 240 m^3.

For calculations, one should take into account the change of the outdoor temperature during the heating period. For example, you can use the regulatory document [11] to determine the average temperature of the heating period in Ukraine, table 1.

Table 1 – Values of average for the month air temperature for city Poltava

Month	October	November	December	January	February	March	April
t_m,°C	7,7	1,3	-3,4	-5,6	-4,7	0,3	9,0

Modes of operation for heat storage device: in winter – discharging (temperature range from t_m÷0 °C); summer – charging, returns accumulated during the winter cold for the needs of the air conditioning system. Working temperature range for plate heat exchanger – heating air from 0°C to supply air temperature. Climatic data are taken for city Poltava and made a preliminary calculation of the phase change heat storage device with use the mathematical model, the results shown in figures 2, 3 and 4.

From the graph, Fig.2, it is seen that the inclusion of heat storage device as a part of the ventilation system keeps the outlet air temperature is not lower than 0 °C, which prevents icing of the plate heat exchanger.

In the diagram (Fig.3) shows the amount of heat that is released or absorbed by the heat storage material, respectively, in the discharging and charging working modes of the seasonal heat storage device. The following it is given a graph of gradual freezing of the ice in the accumulator during the heating period, his maximum weight is 9318 kg.

From the diagram (Fig. 4), we can see that the main mass of the ice formed during January – February, further it is possible to observe the process of his melting.

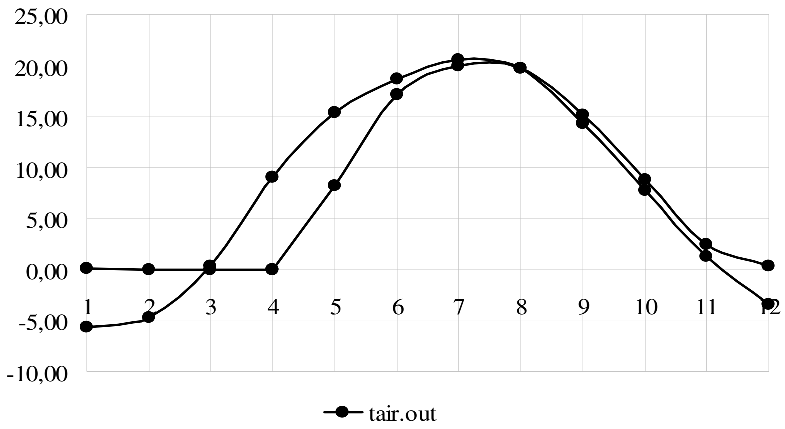

Figure 2 – The graph of air temperature distribution at the output from the heat storage device and the average for the month outdoor air temperature

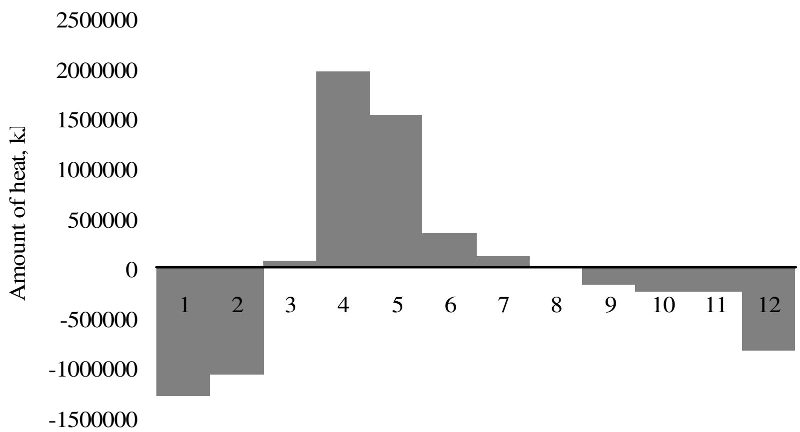

Figure 3 – The chart of monthly distribution of the amount of heat which gives HAM for heat the outside air

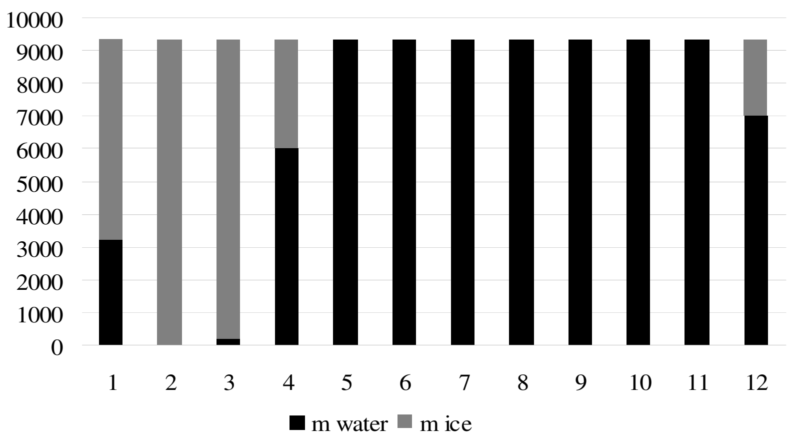

Figure 4 – The graph of monthly distribution of the mass of ice and water in the heat accumulator throughout the heating period

Conclusions. The prospect of switching to supply ventilation system with heat recovery PCHSD is considered that allows to minimize the use of heat energy for ventilation needs of the house and avoid such negative processes as the icing of the plate heat exchanger. On the basis of the equations of thermal balance of the heat storage device, preliminary calculation were performed and graphically the temperature distribution at the exit of the accumulator was depicted, the distribution of the quantity of heat and changes in the amount of water and ice in the heat exchange process was charted.

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