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| Research Article

Thermal Accumulators and the Difference in Heat Storage

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Annotation
In solar thermal and cooling supply schemes, heat storage-based accumulators (such as water, gravel, crushed stones, and others) are widely used. In some cases, heat accumulation is achieved by heating a water layer surrounding stones. At the same time, the working materials used in the above-mentioned heat accumulators, in desert and semi-desert areas, for supplying low-power consumers with hot water, have certain disadvantages, mainly of an economic nature. These include the limited availability of drinking water and the high cost of electricity and thermal energy used to accelerate the process (such as pumps, ventilators, large containers, etc.).

Keywords: Solar energy, electricity, heat, accumulator, water, paraffin, ventilator, pump.

Introduction. Thermal energy accumulators are divided into three types: capacitive thermal accumulators; accumulators that use the latent (hidden) heat of phase transitions; and accumulators based on the absorption of heat during reversible chemical reactions. Conventional thermal accumulators based on high heat capacity materials are quite widespread. In the use of such thermal accumulators, heat is utilized depending on the change in temperature of the physical substance, which either releases or absorbs heat. One of the most specific materials that accumulates heat and is currently used in many helio-systems is water. The inefficiency of such accumulators is undoubtedly due to the increase in heat loss as the temperature of water rises and the large size of these devices. **The use of accumulators based on the absorption of heat during reversible chemical reactions is not currently advisable.** This is because, after several cycles, and due to the imperfection of the chemical reaction process, the properties of the heat-accumulating materials change. In our opinion, accumulators that use the latent heat of phase transitions are currently the most promising. The effectiveness of this method lies in the fact that for many substances, the amount of phase change enthalpy is significantly higher than the amount of heat stored due to the change in temperature.

Method and Result. The application of helio-technical equipment, as indicated by literature and scientific work analysis, shows that the use of solar energy for heating, cooling, and hot water supply is the most promising and practically correct direction. This is because, for this purpose, in some cases, 80% of the fuel used in cities is consumed. However, the widespread use of solar devices for heating, cooling, and hot water production has not been fully implemented for several reasons. These include the lack of technology for producing helio-technical equipment, the high cost of materials, the complexity of automatic control systems, and the insufficient study of some processes occurring in the equipment. In such cases, in order for the system to operate continuously over a 24-hour period, one of the main issues is the heat supply of helio-technical devices, the provision of hot water, and the development and creation of thermal accumulators, due to the variability of solar radiation, its low intensity, and intermittent nature.

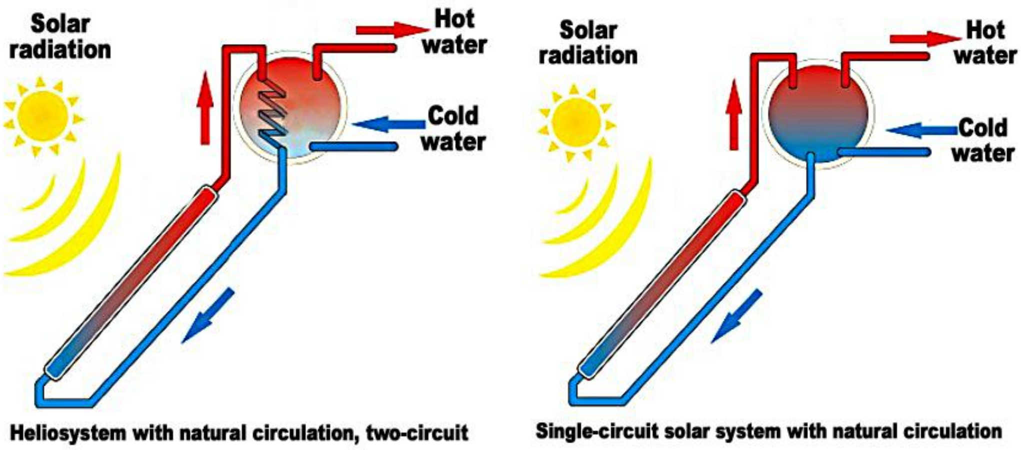

Figure 1. *Schematic view of solar collectors*

Currently, in solar heating and cooling supply schemes, heat storage accumulators based on thermal capacity are widely used (such as water, gravel, stones, and others). In some cases, heat accumulation is carried out by heating a water layer surrounded by stones. At the same time, the working materials used in the above-mentioned thermal accumulators for supplying low-power consumers with hot water in arid and semi-arid regions have some drawbacks, mainly of an economic nature. These include the limited availability of drinking water and the high cost of electrical and thermal energy used in the acceleration of the process (such as pumps, fans, large-volume containers, etc.).

Therefore, selecting efficient heat-collecting materials and, based on this, creating heat accumulators with technical and economic indicators is an urgent issue.

When selecting heat-collecting materials (considering the material's melting point), it is advisable to base the choice on the required water temperature for the consumer. For example, if water is chosen as the heat-collecting material, it will serve as both the heat-collecting and working material, and the heat accumulated per unit mass is:

$Q=m\times c_{\rho}(t_{\mathbf{0}}\ -t_{\beta})$ kJ

m - mass of the heat-absorbing material, kg;

$\mathbf{c_{\rho}}$ - specific heat capacity of the material, kJ/(kg·°C);

$\mathbf{t_0}$ and $\mathbf{t_{\beta}}$ - initial and final temperatures of the heat-absorbing material, respectively, in °C

For example: Using water as the heat-absorbing material, its mass is m=1kg, specific heat capacity c_{ρ}=4.19 kJ/(kg\°C), the initial temperature is t_1=20 °C and the final temperature is t_2=60 °C. What is the amount of heat absorbed by the material?

$Q=m\times c_{\rho}\ (\ t_{ox}-t_{\beta})=1\times 4{,}19\times(60-20)=168$ kJ (heat absorption)

If we use paraffin, a material that changes its aggregate state, as the heat-absorbing material (with $t_{er} = 55^0$ S, $C = 2.3$ kJ, $\lambda_{kat} = 0.15$ Wt/(m^2/S), $\lambda_{suy} = 0.13 \frac{Wt}{\frac{m^2}{C}}$, $\Delta i_{pl} = 168$ kJ/kg), the heat absorbed per unit mass is:

$$Q_{batt} = m[C_{sol}(t_{pl} - t_b) + \Delta i_{pl} + C_{liq}(t_{per} - t_{pl})] \qquad kJ$$

Here:

- ✓ m - mass of the paraffin, kg
- ✓ C_{sol} va C_{liq} - specific heat capacities required for heat conduction in the solid and liquid states, kJ/kg
- ✓ t_{pl}- melting temperature of paraffin, °C
- ✓ t_β - initial temperature of the paraffin, °C
- ✓ Δi_{pl}- heat energy required to convert 1 kg of paraffin into liquid state, kJ/kg
- ✓ t_{per}- temperature of the paraffin after melting, °C

If the temperatures are the same as shown in the example above, the heat accumulated using paraffin is:

$$Q_{bat} = 1[2.3(55 - 20) + 168 + 2.3(60 - 55)] = 80.5 + 168 + 11.5 \approx 260\ kJ$$

The heat provided through the heat transfer medium to melt the paraffin is:

$Q_{er} = G_b \times C_r(t_2 - t_1)$ kJ/hour

G_b - water consumption, kg/hour;

C_r - specific heat capacity of water, 4.19 kJ/(kg·°C);

t_2 , t_1 - temperatures of the heating medium (water) at the inlet and outlet of the accumulator, °C

Heat transfer coefficient during the paraffin melting process:

$$K = \frac{Q_{ht}}{F(t_{at.w} - t_{at.p})} = \frac{G_b \times C_r(t_2 - t_1)}{F(t_{at.w} - t_{at.p})}$$

Here:

Q_{ht} - heat transferred to the paraffin through hot water, Vt;

F - heat exchange surface area of the heat exchanger, m^2;

$t_{at.w}$ - average temperature of the water, °C;

$t_{at.p}$ - average temperature of the paraffin, °C.

Heat transfer coefficient during the cooling of paraffin:

$$K = \frac{Q_{col}}{F(t_{at.p} - t_{at.w})} = \frac{G_b \times C_r(t_1 - t_2)}{F(t_{at.p} - t_{at.w})}$$

Conclusion. In conclusion, it can be said that heat accumulators based on materials that change their aggregate state accumulate more heat at the same temperatures compared to physical (specific heat) accumulators and have a more compact volume. This makes them an attractive solution for various industrial and domestic applications, such as thermal energy storage systems, where efficient and space-saving designs are crucial. Furthermore, the use of phase-change materials (PCMs) in heat accumulators offers additional benefits, including a higher energy storage density and the ability to release heat at a relatively constant temperature, making them particularly suitable for applications that require a stable thermal output. Overall, the advantages of heat accumulators based on materials that change their aggregate state make them a promising technology for optimizing energy efficiency and reducing costs in a wide range of industries.

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