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STORAGE OF THERMAL ENERGY IN PHASE CHANGE MATERIALS USING HYBRID HEATING SYSTEMS

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Abstract: *Thermal energy storage using phase change materials is an important step in solving the frequent problems of heat supply only at times when it is necessary. The paper presents the importance, advantages and applicability areas of latent heat storage units using phase change materials and also information to design heat storage units with this type of substances, consisting of a mixture of saturated hydrocarbons, such as paraffin. Using such a heat storage unit is very profitable because the dimensions are much smaller than a classic one (water) and the heat is stored for a longer period of time, the temperature maintains constant until the whole process of phase change is totally finished.*

Keywords*: Thermal energy accumulator, phase change material, hybrid heating.*

1. Introduction

Transforming solar energy into heat is the most environmentally friendly and economical solution of renewable energy sources (the potential is 60,106 GJ annually). Although, solar thermal installations, have a high energy conversion rate, due to intermittent (periodic) operation, geographic and weather conditions, are generally integrated with other sources of heat (natural gas, liquid or solid fuels, biomass or geothermal) in hybrid systems. The energy that can be obtained on a collector surface of 1 m^2 varies greatly, in Romania, on a sunny day, the average sunshine can reach approx. 1000 W/m^2. (source: ANM, ICEMERG)
There is a constant mismatch between supply and demand for thermal energy produced from renewable energy sources; the problem is not the lack of energy, but finding solutions to supply a sufficient amount of energy, in a usable form, when and where it is needed.

2. Thermal accumulator

Thermal energy storage is an important step in solving the frequent heat supply problems regardless the heat load variation to consumers (heating or domestic hot water preparation). The thermal energy, received from the solar collectors, is currently stored in systems with hot water tank supplied also by other heating systems. The operating principle of a thermal accumulator is the same of a heat exchanger. The storage agent takes the thermal energy from the heating system (solid fuel boilers, gas boilers, heat pumps, solar panels, etc.) through thermal agent, when the heating system supplies a higher amount of energy than is necessary at that time. The heat accumulator stores the heat in the mass of the storage agent and then delivers it as needed, providing users extra comfort. [1], [2], [3]
In the case of domestic hot water obtained from thermal solar panels, the storage capacity is between 13 and 15 liters of water per 1 m^2 of radiant surface. If solar energy is also used as contributor to rooms heating, the storage tanks are cylindrical without an internal heat exchanger (tank in tank) with a larger volume than domestic hot water boilers (about 1000-3000 liters), called puffer tanks for heating. [3], [4]

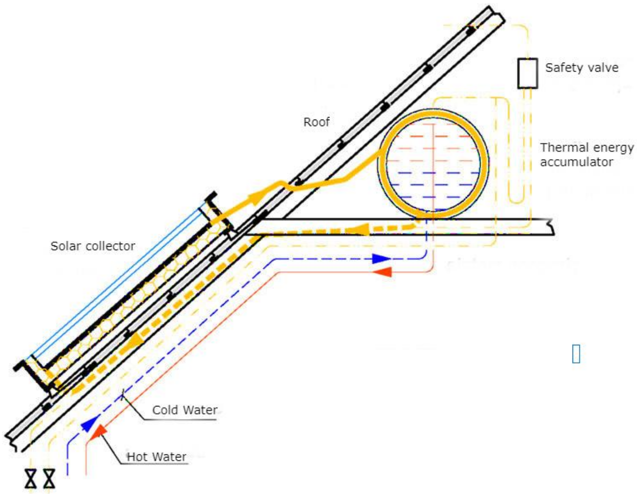

Fig. 1. Scheme of a thermal solar collector with accumulator

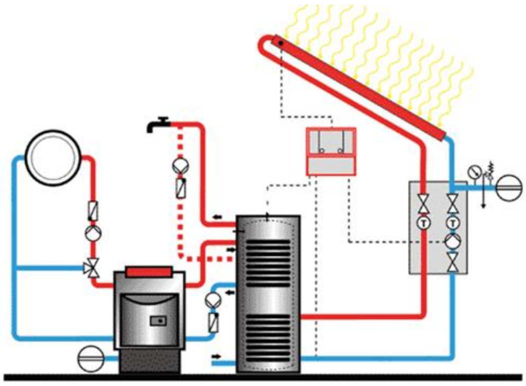

Fig. 2. Hybrid heating system

Taking into account the data obtained from the literature, the thermal solar installations can cover the needs of Domestic Hot Water, considering that a solar thermal panel with the area of 2 sqm provides the necessary for 2 persons, under medium comfort (50 liters of DHW / person / day). The correct sizing of a combined storage facility can fully cover the need for DHW, at least in the warm season (April to September). [3], [4]

The most common heat storage medium is water, due to high specific heat and high density. In order to reduce the volume occupied by the thermal accumulators and to increase the amount of stored heat, two-phase substances can be used. Phase change materials, change their aggregate state when they receive or dissipate heat, but without changing the temperature throughout the phase change process, they can store up to 5-14 times more heat per unit volume than conventional ones. Thus, for 1 m^2 of energy storage area, a volume of 1-3 l of storage agent would be needed compared to 13-15 l for water. [1], [2], [3], [4]

To accumulate and release the required amount of energy, these systems depend basically on the temperature, the latent heat of phase change, of the storage agent.

Phase change substances may be organic (paraffins, esters, glycols) or anorganic salts (salt hydrates and metals class) and, depending on their chemical composition, have different energy storage properties.

The operating principle of paraffin accumulators is similar to the classical ones, so the thermal storage medium, the paraffin, being in solid state, takes the heat from the heating system (solid fuel boilers, gas boilers, heat pumps, systems with solar panels etc.) through heating agent, and starts to melt (phase change). Throughout the melting process, the wax takes heat from the heating agent, but the temperature remains constant (approx. 60^oC – paraffin melting point). After the melting process has ended, i.e., when the total amount of paraffin in the solid state has completely turned into liquid state, it is overheated to the temperature at which the heat exchange of these agents is greatest. The thermal agent circulating in the heating or/and domestic hot water system, takes over this heat and distributes it to consumers as needed. Thus the process will reverse (from liquid to solid state), but the heat transfer and phase exchanges will be the same. [2]

3. Comparative analysis of water and phase change accumulators

Considering that the useful temperature of 50°C of the heating agent is sufficient for domestic hot water and for rooms heating, it was made a calculation for the energy demand, so that water yields the same energy value as if paraffin was used and cooled by at 80°C to 50°C, (see equation 1. - The calculation of the amount of energy required to heat the accumulator media from 20 to 80^{o}C.)

$$Q_{accum} = m_{media} \cdot c_{p\text{-}media} \cdot \Delta T \text{ [kJ]} \quad (1)$$

where: m_{media} – the mass of accumulator media; $c_{p\text{-}media}$ – specific heat, 4180 [J/kg·K] for water and 4324 [J/kg·K] for paraffin at 20 [^{o}C]; ΔT – temperature difference.
The graph below shows a comparison of thermal energy storage properties for water (green) and technical paraffin (blue).

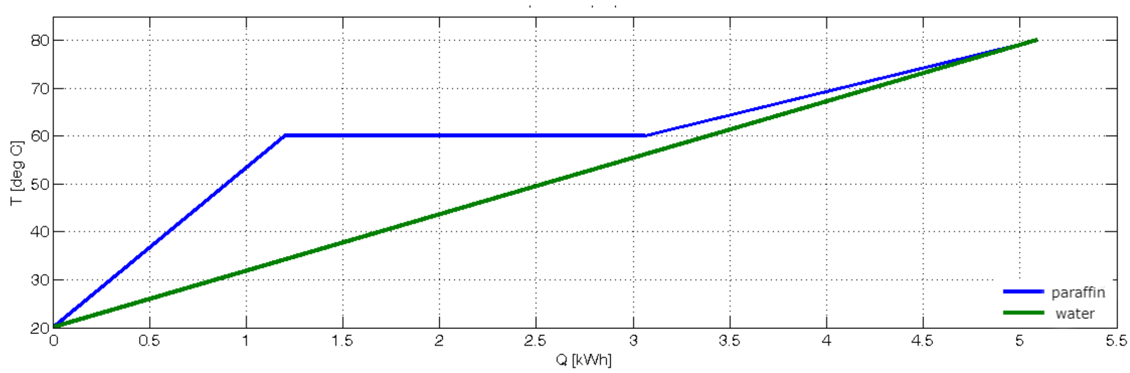

Fig. 3. Comparison of thermal energy storage for water and paraffin

In the graph bellow, the blue curve represents the energy requirements to heat the paraffin from ambient temperature of 20 ºC to a temperature of 80 ºC. The green curve shows that if water is used as a storage medium for the same temperature difference (20 °C to 80 °C), receiving the same amount of heat (5.1 kWh), the mass of the storage medium is higher with about 100%. Comparing the two curves (blue and green) in the situation where the storage agent gives up the heat to the primary agent (from the heating installation) it is found that in the case of the phase change accumulator the temperature is higher for the same amount of energy consumed as compared to a conventional thermal accumulator. The red curve was drawn to highlight that to cool the storage medium from 80 ºC to 50 ºC, using the same amount of energy, the mass in the case of water is about 100% higher. (see equation 1). This also results in the fact that for the previously obtained storage tank (water), a double amount of energy is needed to heat it from 20 °C to 80 °C. In order to develop such products, it is recommended, to perform CFD numerical analysis, which facilitates proper sizing of the thermal accumulator for concrete applications and after the numerical models have to be validated through practical experiments [5], [6]. Regarding the flow of thermal agents, modern solutions described in [7], [8], [9], as well as monitoring the functional parameters.

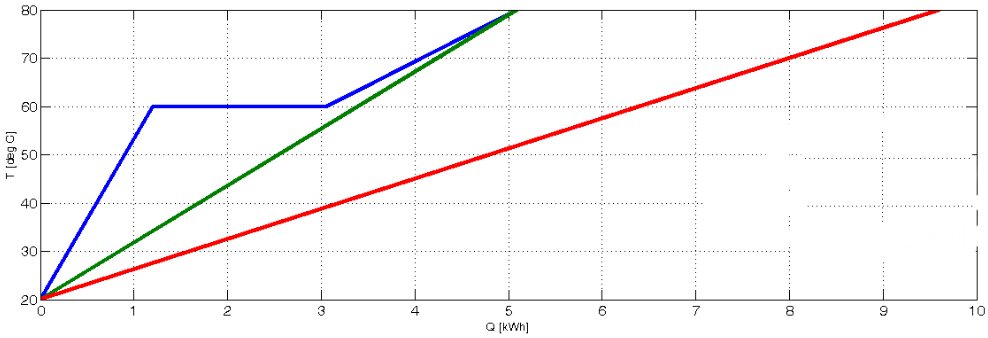

Fig. 4. Comparison of energy requirements to heat 60 ºC for water and paraffin

4. Conclusions and discussions

The volume of national and international researches in the field of renewable energies is increasing, and penetration with new ideas can create important collaboration opportunities.
The accumulators analyzed within the paper, have significant market potential, contributing to the exploitation of renewable energies, a field in which Romania has a very high potential, but with few exceptions, untapped. The lack of exploitation is also due to the lack of products tailored to the purchasing power of the beneficiaries.
The analyzed accumulators are addressed to small users, individual households; the solutions in principle allow them to be adapted for the design of various size installations, thus covering a wide range of demands. Apart from the individual users, the facilities are also useful for various institutions, commercial spaces, offices. The contribution, of this type of products, to increase the quality of users' lives is significant, as products contribute to lowering the costs of heating.
This type of products can be manufactured by many well-equipped national enterprises, which are currently struggling to create a main or secondary development.

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