A REVIEW ON SOLAR WATER HEATER WITH PHASE CHANGE MATERIALS

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ABSTRACT

The use of solar energy in solar water heater by using a phase change material (PCMs) in storage tank is the effective way of storing the thermal energy. Within the past decade uses of PCMs for heating and cooling applications for buildings have been investigated. This paper summarizes the investigation and analysis of thermal energy storage incorporating with PCM for use in solar water heaters. Storing solar energy with the help of phase Change materials (PCMs) and utilizing this energy to heat water for domestic purposes during the night time. The system consist of two absorbing unit one of them is solar water heater other a heat storage unit consisting of PCM (paraffin).As this experiment is carried out for getting a hot water in night with help of phase change material. The storage unit consists of small cylinders which are made of aluminum filled with paraffin wax as a heat storage unit. During the day time the solar collector absorb the heat from sun and the water is heated with the help of solar radiation. The heated water transfer it heat to phase change material (PCMs). The phase change material undergoes the phase change by absorbing the latent heat and the excess heat is stored in the form of sensible heat. The water supply in the night is routed to the storage unit using a suitable control device. The heat is recovered from the unit by passing at room temp through it. The storage tower is completely insulated to prevent loss of heat. The efficiency of this system is scrutinized for the solar conditions.

Keywords: Solar Energy, Thermal Energy Storage, Phase Change Material, Water Heating System.

I INTRODUCTION

Energy is the backbone of human activities. Historically fossil fuel in its solid phase, i.e. wood and coal, has been the prime source of energy. The increment in global energy demands due to population growth and 20th century industrial revolution leads fossil fuel through a transitional phase. The world saw a rapid growth of the use of solar warm water after 1960. Solar energy is an important alternative energy source that will more likely be utilized in the future. One main factor that limits the application of solar energy is that it is a cyclic, time dependent energy resource. Therefore, solar energy systems require energy storage to provide during the night and overcast periods. In solar energy applications, TES can provide savings in systems involving either simultaneous heating and cooling. Solar energy applications require storage of thermal energy for periods ranging from very short durations to annual cycle time scales. Most TES applications involve a diurnal storage cycle. PCMs absorb and emit heat while maintaining a nearly constant temperature within the human comfort range 20 to 30° C

The main objective of the paper is to improve the output of solar water heater by using the PCM jacket. Using a phase change material (PCMs) jacket we can wrapped over the tank. By using $CaCl_2$-$12H_2o$ salt hydrate which is an inorganic phase change material having melting point 29.8°C and latent heat 174 KJ/Kg.

II Energy storage methods

1. Mechanical energy storage
2. Electrical storage
3. Thermal energy storage
4. Thermo chemical energy storage

III Classification of thermal energy storage system

a) Thermal energy storage

1) Sensible solid

i) Liquid

ii) Solid

2) Latent heat

i) solid-solid

ii) solid-liquid

iii) liquid- gaseous

b) Chemical energy storage

i. Thermal Chemical Pipe Line

ii. Heat of Reaction

iii. Heat Pump

IV Latent heat storage materials

Phase change materials (PCM) are ''Latent'' heat storage materials. The thermal energy transfer occurs when a material changes from solid to liquid, or liquid to solid. This is called a change in state, or ''Phase.'' Initially, these solid–liquid PCMs perform like conventional storage material, their temperature rises as they absorb heat. Unlike conventional (sensible) storage materials, PCM absorbs and release heat at a nearly constant temperature. They store 5–14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock. A large number of PCMs are known to melt with a heat of fusion in any required range. However, for their employment as latent heat storage materials these materials must exhibit certain desirable thermodynamic, kinetic and chemical properties. Moreover, economic considerations and easy availability of these materials has to be kept in mind.

The PCM to be used in the design of thermal-storage systems should passes desirable thermo, physical, kinetics and chemical properties which are as follows:

a) Thermal properties

1) Suitable phase-transition temperature
2) High latent heat of transition.
3) Good heat transfer.

b) Physical properties

1) Favorable phase equilibrium
2) High density.
3) Small volume change.
4) Low vapour pressure.

c) Kinetic properties

1) No super cooling.
2) Sufficient crystallization rate.

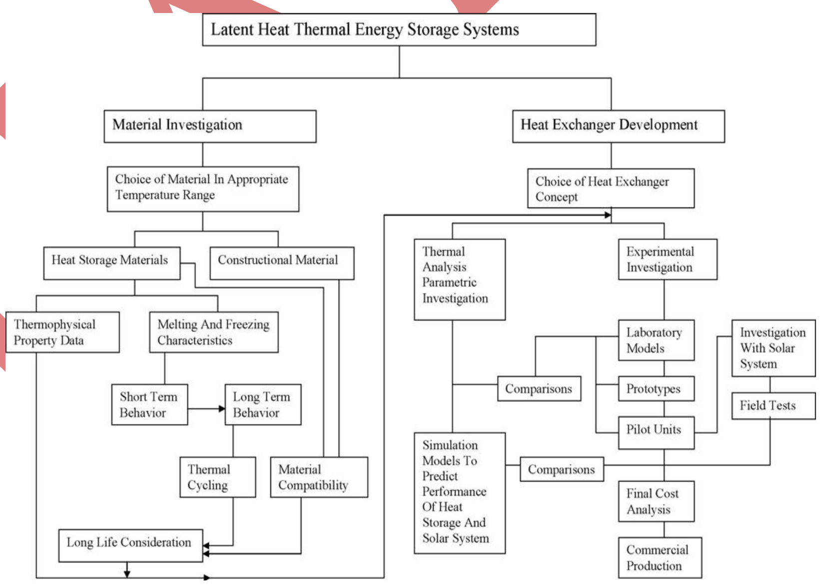
d) Chemical properties

1) Long-term chemical stability.
2) Compatibility with materials of construction.
3) No toxicity.

PCM can suffer from degradation by loss of water of hydration, chemical decomposition or incompatibility with materials of construction. PCMs should be non-toxic, non-flammable and non-explosive for safety.

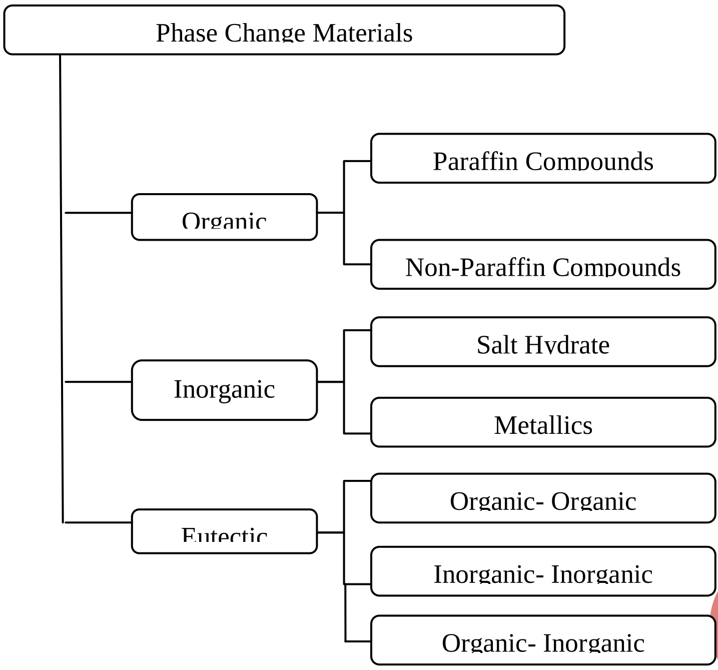
Table 1: Physical Properties of Some Paraffins.

Flow chart showing different stages involved in the development of a latent heat storage system



V Classification of PCMs

A large number of phase change materials (organic, inorganic and eutectic) are available in any required temperature range. A classification of PCMs is given as follow.



Paraffin	Freezing point Degree(°C)	Heat of Fusion KJ/Kg
6106	42-44	189
P116	45-48	210
5838	48-50	189
6035	58-60	189
6403	62-64	189
6499	66-68	189

There are a large number of organic and inorganic chemical materials, which can be identified as PCM from the point of view melting temperature and latent heat of fusion. Organic phase change materials Organic materials are further described as paraffin and non-paraffin. Organic materials include congruent melting means melt and freeze repeatedly without phase segregation and consequent degradation of their latent heat of fusion, self-nucleation means they crystallize with little or no super cooling and usually non-corrosiveness.

Paraffin

Paraffin wax consists of a mixture of mostly straight chain alkanes CH_3–(CH_2)–CH_3. The crystallization of the (CH_3) chain releases a large amount of latent heat. Both the melting point and latent heat of fusion increase with chain length. Paraffin qualifies as heat of fusion storage materials due to their availability in a large temperature range. Due to cost consideration, however, only technical grade paraffin may be used as PCMs in latent heat storage systems. Paraffin waxes are reliable, predictable, less expensive and non-corrosive. They are chemically inert and stable below 500 °C, show little volume changes on melting and have low vapour pressure in the melt form. For these properties of the paraffin, system-using paraffin's usually have very long freeze–melt cycle.

VI REVIEW OF SOME RESEARCHERS

Vikram D et al.,[1]:- The thermal behavior of LHTES system was investigated experimentally for various operating conditions. LHTES system using the phase change material (PCMs) in cylindrical form is designed and fabricated with an effective storage capacity of 7 lit for the need of four members. solar water heater with phase change material working on two heat absorbing unit one with solar water heater and another is heat storage unit which consist of phase change material (PCMs). Paraffin wax is used as phase change material having a latent heat of 154 kJ/kg .As this experiment was carried out for getting a hot water in night with the help of phase change material (PCMs).Flat plate collector was used to heat the water in the panel. It was conclude during the charging process the temperature of water increases, but the system efficiency decreases with time.

Mohammad Ali Fazilati et al., [2]:- In this research, experimentally investigated the used of phase change material in solar water system with and without phase change material (PCMs) was studied and the effect of solar radiation intensity (i.e. weak, mean and strong intensity). In solar water heater system the storage medium was made up of paraffin wax which is a phase change material (PCMs) having a melting point of 55°C and latent heat of 187 kJ/kg. The solar tank was made up of jacket shell type. It was concluded that by using the phase change material the energy storage density can be increased up to 39% and the energy efficiency is enhanced up to 16 %. Also it was observed that we can get a hot water with specified temperature at 25% longer time by using the phase change material (PCMs) in storage tank in solar water heater system. In a charging mode, the system can supply hot water extended up to 25 % in 80°C.

Al–Hinti et al., [3]:-In this paper, experimentally investigated in the conventional solar water heating system with and without using the phase change material (PCMs).The phase change material used in the system was paraffin wax. Aluminum container contains paraffin wax in the form of cylindrical shape. The cylindrical (PCMs) were arranged in two levels. The experiment was carried out in two types, one with electric heater and other with solar flat plate collector. The (PCMs) storage firstly demonstrated with the aid of an electric heater on a storage tank with and without (PCMs) container. The storage performance was also investigated when connected to flat plate collectors in a closed-loop system with conventional natural circulation. It was conclude that the electric heater configuration can result in a 13–14 °C advantage in the stored hot water temperature over extended periods of time. The flat plate collector in a closed-loop system gives the better result with paraffin wax (PCM) as compared with electric heater by using with variable solar energy input. From conventional flat plate collectors, the water-PCM storage succeeded in keeping the water temperature over 45 °C under all operational and climatic conditions.

Anant Shukla et al., [4]:- This review paper was focused on the available thermal energy storage technology with PCMs with different applications. According to the researcher point of view latent heat thermal energy storage is one of efficient ways to store the thermal energy for heating water which is received from sun. As per the experimentally investigated and analysis this paper represents the brief idea of thermal energy storage by using the phase change material (PCMs) with and without in solar water heating system. Researcher used phase change material with high latent heat and with large surface area for heat transfer is required for a better thermal performance of solar water heater. Paraffin wax was used as phase change material (PCMs).An inbuilt thermal storage can be an alternative to the present day solar water heater with less complicated design and cost effectiveness. Those technologies is very beneficial for the humans and as well as for the energy conservation.

Atul Sharma et el al., [5]:- In this review paper, experimentally investigated behavior of PCM with thermal energy storage system.PCM can freeze and solidify at wide range of temperature in number of applications. This paper also investigated the brief idea of various thermo physical properties of phase change materials. The heat storage applications used as a part of solar Water-heating systems, solar air heating systems, solar cooking, solar green house, space heating and cooling application for buildings, off-peak electricity storage systems, waste heat recovery systems.

Monica F. Bonadieset et al., [6]:- Experimentally studied, a system integrating evacuated tube collectors with heat pipes with a storage unit using melted paraffin wax to store thermal energy. A shell-and-tube heat exchanger was embedded within the paraffin wax storage with a volume of 0.23 m^3. The heat exchanger includes two loops: one for glycol to transfer heat to the paraffin and one for water to extract heat from the melted paraffin. The maximum operating temperature of the glycol/water mix heat transfer fluid was approximately 65 ^{0}C when the fluid flowed at 3.78 l/min. City water at approximately 11.34 l/min was used to test the water heating capabilities of the unit. It was conclude that the heat stored and extracted during the melting and freezing processes, respectively.

W. Saman et al., [7]:- In this paper, studied thermal performance of PCM thermal storage unit for a roof integrated solar heating system and which was based on both experimental results and a theoretical two dimensional mathematical model of the PCM employed to analyze the transient thermal behavior of the storage unit during the charge and discharge periods. The analysis takes into account the effects of sensible heat which exists when the initial temperature of the PCM is well below or above the melting point during melting or freezing. The results were compared with a previous analysis based on a one dimensional model which neglected the effect of sensible heat. It was concluded that the effect were reflected in sharp increase in the outlet air temperature in the initial periods of melting and a sharp decrease in the initial periods of freezing. A higher inlet air temperature increases the heat transfer rates and shortens the melting time. During freezing, a lower inlet air temperature increases the heat transfer rates and shortens the freezing time. Likewise, a higher air flow rate increases the heat transfer rate and shortens the melting time but increases the outlet air temperature. For freezing, a higher air flow rate increases the heat transfer rate and shortens the freezing time but reduces the outlet air temperature.

Rozanna et al., [8]:- Experimentally investigated the effect of using a lauric-stearic acids (PCM) eutectic mixture at 75.5:24.5 w/w with melting point of 34.1ºC and latent heat of 171 kJ /kg respectively in gypsum board. Gypsum boards were Immersed 1 hr in PCM and the thermal characteristics before and after immersion were investigated. The gypsum board samples (6 x 15 x1.25/0.6 cm) were immersed for 1 hr in the eutectic mixture at 60ºC.It was conclude that The 12.5 mm board absorbed 38.0% PCM and differential scanning calorimeter (DSC) showed that the melting point and latent heat were 34.0ºC and 50.28 kJ kg-1,respectively. For 6 mm board, PCM absorption was 39.2% with the melting point of 34.0ºC and the latent heat of 52.87 kJ /kg.

VII CONCLUSION

From this review, various ways of increasing the temperature of water or air by using different phase change material in different application. Using a Paraffin wax as a phase change material, we can increase the performance of system in different applications because it is non toxic and easily available with a melting point of 55^0c and 184 KJ/Kg. The heat storage applications used as a part of solar water-heating systems, solar air heating systems, solar cooking, solar green house, space heating and cooling application for buildings, off-peak electricity storage systems, waste heat recovery systems. The review of all this paper also presents the melt fraction studies of the few identified PCMs used in various applications for storage systems with different heat exchanger container materials.

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