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# Review of Solar Water Heating System Using PCM

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***Abstract*:** *Thermal energy storage has always been one of the most critical components in residential solar water heating applications. Solar radiation is a time-dependent energy source with an intermittent character. The heating demands of a residential house are also time dependent. However, the energy source and the demands of a house (or building), in general, do not match each other, especially in solar water heating applications. The peak solar radiation occurs near noon, but the peak heating demand is in the late evening or early morning when solar radiation is not available. Thermal energy storage provides a reservoir of energy to adjust this mismatch and to meet the energy needs at all times. It is used as a bridge to cross the gap between the energy source, the sun, the application and the building. So, thermal energy storage is essential in the solar heating system. Therefore, in this paper, an attempt has been taken to summarize the investigation of the solar water heating system incorporating with Phase Change Materials (PCMs).*
***Keywords:*** *Phase Change Materials, Latent Heat, Thermal Energy Storage, Solar Water, Solar*

## I. Introduction

Each and every human activity demands energy in some form or other. Our requirement for energy is increasing day by day with every advancement in the various fields. This ever increasing need of energy has put a lot of stress on the non renewable resources which are limited in quantity. Hence it has now become a need to find alternative sources of energy and this need of alternative source of energy can very well be fulfilled by the renewable sources of energy if utilized properly. The main drawback of renewable energy resources is that they are dependent on time, considering the case of solar energy; the availability is restricted only to day time. So it becomes necessary to find ways to trap and store solar energy for its easy utilization during night time or during overcast conditions

These materials can store energy by the melting at a constant temperature. No material has all the optimal characteristics for a PCM, and the selection of a PCM for a given application requires careful consideration of the properties of various substances. Over 20,000 com-pounds and/or mixtures have been considered in PCM, including single component systems, congruent mixtures, eutectics and peritectics. The isothermal operating characteristics (i.e. charging/discharging heat at a nearly constant temperature) during the solidification and melting processes, which is desirable for efficient operation of thermal systems. The value of the latent heat is very important, because the higher latent heat results higher storable heat quantity. According these aspects we can choose from several materials. We have to mind the chemical properties, the thermal expansion and the aspects of safety. PCMs in the 50 to 1000 temperature range have been proposed to water heating and o -peak electrical heater applications. Wax is the most commonly used commercial organic heat storage PCM. Paraffin waxes are cheap and have moderate thermal energy storage density but low thermal conductivity and, hence, require large surface area. In our current project we are considering the same PCM. During the charging process the water is circulated through the tank and the solar collector unit continuously. The water absorbs solar energy sensibly, and exchanges this heat with the PCM in the PCM storage tank, which is initially at room temperature. The PCM slowly gets heated, sensibly at first, until it reaches its melting point temperature. As the charging proceeds, energy storage as Latent heat is achieved as the Paraffin wax melts at constant temperature (62±2°C). After complete melting is achieved, further heat addition from the water causes the PCM to superheat, thereby again storing heat sensibly. The charging process continues till the PCM and the water attain thermal equilibrium. Temperatures of the PCM and water at the outlet are recorded at intervals of 3 hours. The PCM is charged through the day, whenever hot water is not demanded by the user. The discharging process used is termed as batch wise process. In this method, a certain quantity of hot water is withdrawn from the water tank and readings are taken. This is then repeated for intervals of 3 hours, in which time transfer of energy from the PCM would have occurred. This procedure is continued till PCM reaches a temperature of 560C. First of all we have taken the trial on the Solar Water Heater without using phase change material

**Selection of Phase Change Material**
In order to select the best qualified PCM as a storage media some criteria were considered according to thermal properties:

- The melting point of the PCM must be lying in a practical range of operation. Temperature interval going from 25 °C to 70 °C.
- The latent heat should be as high as possible to minimize the physical size of the heat storage. A high thermal conductivity would assist the charging and discharging of the energy storage.

According to chemical properties, a suitable Iraqi paraffin wax was used. Due to its physical properties, it has limited changes in density to avoid problems with the storage tank, low vapor pressure, and favorable phase equilibrium. Moreover paraffin wax is available in large quantities and cheap in order to make the system economically feasible. The paraffin is used as PCM that has a melting temperature of 45 ± 1°C and latent heat of fusion of 217kJ/kg.

**Paraffin:-** one of the most reliable phase change materials which are being extensively used nowadays as heat storage material in most of the thermal storage units is paraffin. Paraffin is popularly used because of its properties such as large latent heat and thermal characteristics. The thermal characteristics of paraffin are varied phase change temperature, low vapor pressure in the molten state, negligible super cooling, appreciable thermal and chemical stability and also self-nucleating behavior. A long freeze melt cycle is experienced by the systems which use paraffin as the phase change material in their thermal energy storage unit. Paraffin is made of a mixture of long chain of n-alkanes [CH3-(CH2)-CH3]. Properties such as latent heat of fusion and melting point increases as the length of chain is increased. Availability in large temperature ranges is an important advantage of paraffin and hence is used as heat of fusion storage material. Eg:-hexadecane, pentadecane, tetradecane etc

**Some Paraffin and their properties**

| Paraffin | Freezing point (0C) | Heat of fusion (KJ/Kg) |
|---|---|---|
| $C_{12}H_{16}N_2O_3$ | 47-50 | 189 |
| C18H6BiBr9O3 | 66-68 | 189 |
| $CH_5N_3S$ | 45-48 | 210 |
| C6H14 | 62-64 | 189 |

**Properties of paraffin wax thermo-physical**

| **Descriptions** | **Value** |
|---|---|
| Melting temperature | 46.7 0C |
| Thermal conductivity(solid) | 0.1383 W/m 0C |
| Thermal conductivity(Liquid) | 0.1383 W/m 0C |
| Specific heat (solid) | 2890J/Kg.K |
| Specific heat (Liquid) | 2890J/Kg.K |
| Density(Solid) | 947Kg/m3 |
| Density(Liquid) | 750Kg/m3 |
| Latent Heat | 209KJ/Kg |

**Calculation**

Phase 2

Phase1

We calculated the cooling rate of the water in the water tank after heating the water for 6hrs sunlight.

**Table 1:** Cooling rates of Water in General SWH

| Time elapsed (hrs) | Temperature$^0$C |
|---|---|
| 0 | 75 |
| 3 | 70 |
| 6 | 66 |
| 9 | 62 |
| 12 | 59 |
| 15 | 56 |
| 18 | 54 |
| 21 | 52 |

We know the standard formula for efficiency calculation

Efficiency, $\eta = \frac{\text{Heat energy output}}{\text{Heat energy input}}$

= Qout /Qin

Now,tocalculateoutputHeatenergyQout=
Heat energy absorbed by water

$\rho \times V \times C_{pw} \times (T_f - T_i)$

let's calculate heat supplied by solar radiation Average heat radiated in a day, Pin = 1170 $W/m^2$
Hence, Qin = Pin ×area of panel× Δ t

The absorption of radiated heat is only 96%

In this phase we were calculating the efficiency of Solar Water Heater. The parameter s for calculating the efficiency of Solar water heater as shown in Table

**Table 2:** Efficiency Parameters

| **Parameters** | **Symbol** | **Value** |
|---|---|---|
| Volume of water | V | 20liter |
| Initial Temperature of water | Ti | 360C |
| Heat radiated in day | Pin | 1170 Watts |
| Time elapsed | t | 6hrs |
| Final Temperature of water | Tf | 750C |

effective. So, effective heat radiated on panel
$Q_{in,effective}$ = 0.96 Qin Now, calculating efficiency of general solar water heater without using phase change material

$\eta = Q_{out} / Q_{in,effective}$

Now, calculating cooling rate and the efficiency of the solar water heater by adding PCM (Wax).

We added 9kg PCM (wax) in PCM tank as 100 liter water requires 36kg of PCM. Phase 1

We calculated the cooling rate of water in the water tank by adding PCM and heating water for 6 Hrs.

**Table 3:** Cooling rates of Water in SWH with PCM Phase 2

| Time elapsed (hrs) | Temperature of water $^0$C |
|---|---|
| 0 | 68 |
| 3 | 65 |
| 6 | 63 |
| 9 | 61 |
| 12 | 60 |
| 15 | 59 |
| 18 | 57 |
| 21 | 56 |

Now, specification of PCM,
Initial temperature of PCM = 36$^0$C Temperature of fusion = 60$^0$C Final temperature of PCM = 65$^0$C
Specific heat of solid PCM = 2.5 $\frac{KJ}{KgK}$

Specific heat of molten PCM =215 $\frac{KJ}{KgK}$

Then calculate the efficiency of solar water heater.

The parameters for calculating the efficiency of solar water heater are shown in Table 2.4.

**Table 4:** Efficiency Parameters

| **Parameters** | **Symbol** | **Value** |
|---|---|---|
| Volume of water | V | 20liter |
| Initial Temperature of water | Ti | 400C |
| Heat radiated in day | Pin | 1170 Watts |
| Time elapsed | t | 6hrs |
| Final Temperature of water | Tf | 680C |

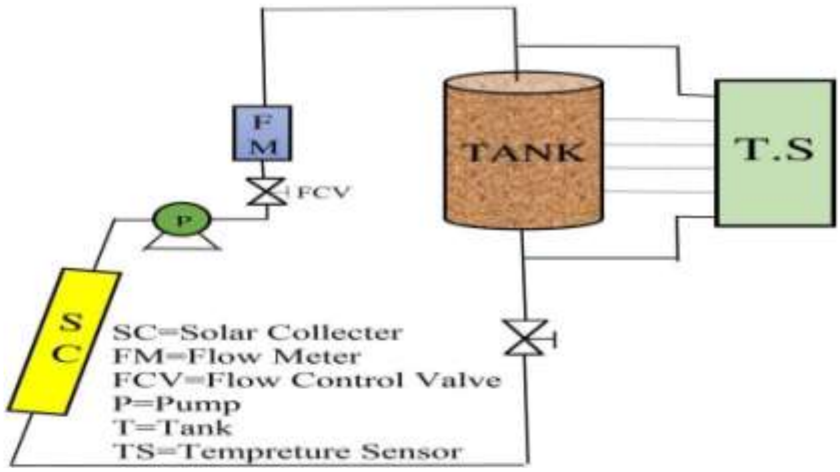
Now, calculating efficiency of solar water heater, Efficiency, ɳ = = Qout / Qin

Now, calculating heat accumulated in the solar collector, which is sum of energy gained by water and same by PCM.

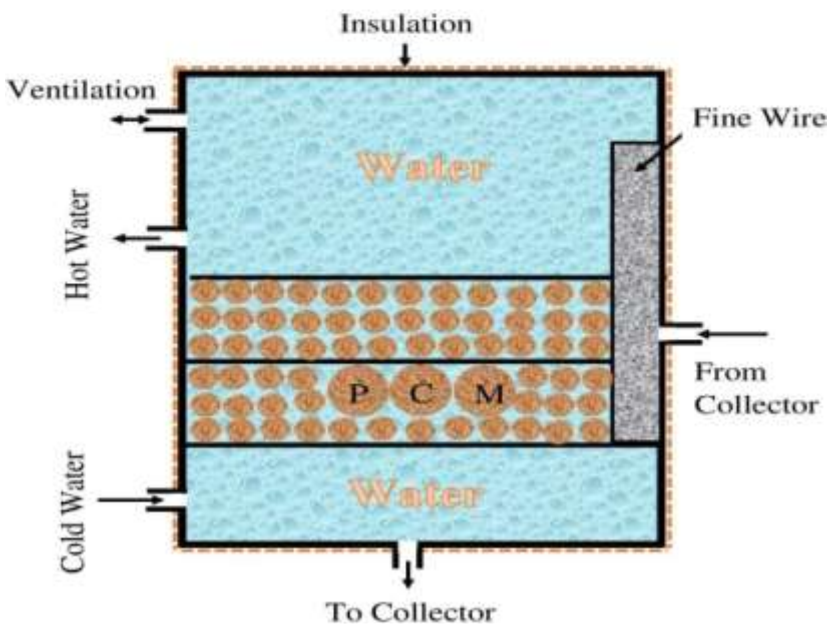
Energy gained by water =ρ×V×$C_{pw}$ × ( $T_f$ - $T_i$ )

Energy gained by water = Energy accumulated by solid PCM + Heat of fusion + Energy accumulated by molten PCM

Qout = Energy gained by water + Energy gained by PCM ɳ= Qout / Qin;eff




Setup Diagram of SWH




Storage Tank of SWH

## II. Conclusion

Solar water heating system plays an important role in sustainable energy management in Indian households as well as worldwide. Such an effort will not only be useful in improving the quality of life but also in environmental protection. This review paper is focused on the past & current research of energy storage through PCMs for solar water heating systems. This paper will also help to find the suitable PCM and provide the various designs for solar water heating systems to store the solar thermal energy.

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