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# Design and Fabrication of Solar Water Heater with Phase Change Material and Concentrating Lens

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***Abstract:*** ***The solar energy is the most abundant energy source in the world and it is pollution free. The energy storage will reduce the wastage of the fuel and it leads to saving premium fuel and make the system more cost effective. The present work has been embarked upon to the possibility of storing solar energy using phase change material (PCM) and uses this energy to heat water for domestic purpose after the temperature drop.***
***Solar is being a renewable source of energy, which is used to store heat in the storage tank and enclosed PCM are kept inside the storage tank. The system consists of two functioning of heat absorbing system. One of them is a solar water heater and the other a heat storage unit consisting PCM.***
***The concentrating lens is to focus the sunlight on solar collector, thus concentrate sunrays to be maximum. During charging process heat can be stored as latent heat, the same heat can be utilized during discharging process by circulating cold water. The PCM used is intended to enhance the heat storage capacity of the conventional solar tank used in domestic solar water heaters. Experimental result of our project shows with use of PCM the stored heat can be used to heat water during the night time reduces cooling rate, efficiency and heat storage capacity increases.***
***Keywords: Solar water heater, Phase change material (PCM), Thermal energy storage, concentrating lens***

## I. INTRODUCTION

Solar water heater is the renewable source of energy. Solar energy is widely available on earth. Solar water is which converts the light energy in to useable heat energy for heating the cold water using solar flat plate collector. Different varieties of solar water heater are available t different cost to give solutions for the problems such as climates and latitudes. Solar water heaters are widely used for commercial purpose such as in houses, hotels and also in industries. The solar water heaters are used to heat the fluid that passes into the solar flat plate collector.

Here the fluid is the water; it is heated directly or by concentrating lens.

The solar energy from the sun is absorbed by solar collector and the heat is used to convert the cold water to hot water. The passive type solar water system are cost less and require low maintenance and the efficiency is less. The active type solar system uses one or more than two pump system. The pump is used to circulate the water or the fluid. This active type solar system is more expensive and high maintenance is required but the efficiency is more.

Phase change material (PCM) is a substance which absorbs the heat energy as fusions and it melts because of heat energy, in this stage the heat energy is store by the phase change material. the stored energy is released when there is temperature drop. The stored heat is absorbed and released when the material changes to the solid to liquid and liquid to solid[2].

The PCM are classified as heat storage unit.

Organic and inorganic compounds are the two major common groups of the PCM[1]. The organic PCM are chemically stable, no sub cooling, and non-corrosive and have high latent heat per unit weight. Inorganic PCM are non-flammable, low cost, high thermal conductivity and have high latent heat per unit.

The PCM have adjustable melting point which can be used in most important criteria for selection of PCM. Latent heat storage can be achieved through solid to liquid, liquid to solid, solid to gas and liquid to gas phase change. In our project we use the sodium thiosulfate is an inorganic components with the formula is $Na_2S_2O_3{\cdot}xH_2O$[1]. It is available as the white or colourless pent hydrate $Na_2\ S_2\ O_3{\cdot}5H_2O$. Solid is an efflorescent crystalline substance that dissolves with water.

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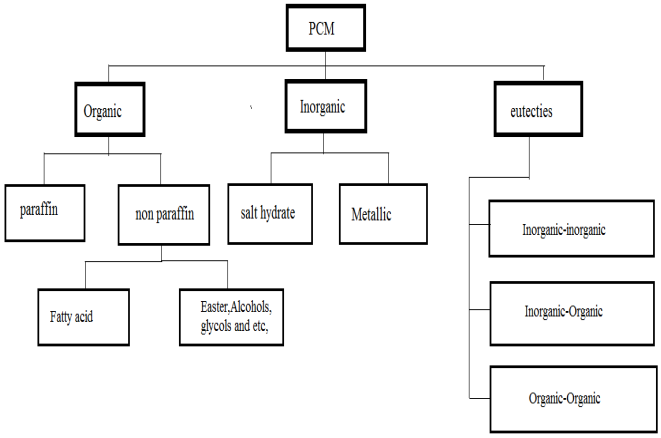



Fig. 1 Classification of PCM

## II. DESIGN DIAGRAM

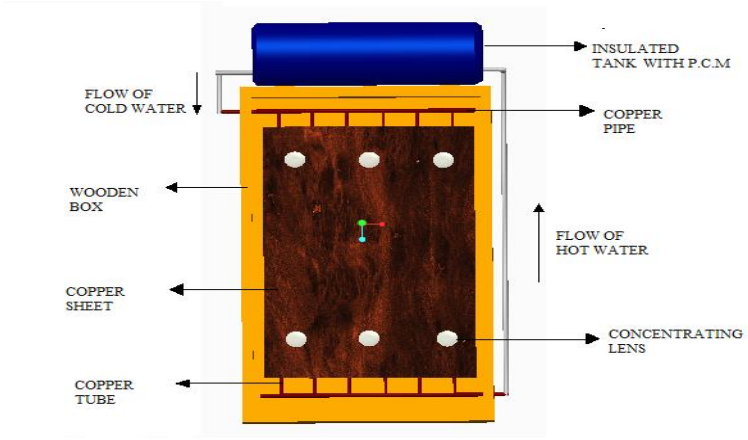



Fig. 2 3D view of solar water heater

## III.LITERATURE REVIEW

S. BharathSubramaniam, KanithiTerison, KolnatiSudhir and Yaswanth Reddy .et.al.,A phase change material has connection with the thermal energy storage system to analyse the performance of Integrated Collector Cum Storage Solar Water Heater. The Latent Heat Storage was preferred as it stores the excess thermal energy beyond the sunshine and releasing it when there is energy demand. There are many phase change materials that melted and solidifies over a range of temperature. During the night, it was found that the Latent Heat Storage was effective as it allows minimum energy losses and conservation of energy. The maximum water outlet temperature was achieved by using paraffin wax and so this PCM can be considered as the most beneficial for the solar application from techno-economic aspects.

Sarvesh R.Sawant, Suprabhat A.Mohod.et.al., The fast growing problem of the depletion of the available non renewable energy resources has focused the world's attention on the need of proper use and harvesting of the renewable energy resources. One of the important renewable energy resources is solar energy. In recent times the use of PCM (phase change materials) for storage of thermal energy in solar water heaters has come forward as an efficient way for trapping and storing solar energy. Thermal energy storage systems which have paraffin as the PCM are under study here. These systems trap and store the solar energy during daytime with the help of PCM (paraffin) which can later be used during night time to heat water. This heated water can then be used for domestic as well as industrial purposes. Thermal energy storage with PCM has been termed as an effective way to store thermal energy on the basis of the recent experimental studies highly due to their large heat trapping capacity and also because of their isothermal characteristics. These systems are examined properly to check their efficiency.

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Paras Sachdeva.et.al., Solar water heater (SWH), one of the most popular solar thermal systems, accounts for 80% of the solar thermal market worldwide. This paper presents the past work on solar water heater using phase change material. PCM has used in different part of thermal heating networks including shell and tube type collectors, flat pate collectors and evacuated tube collectors. Recent findings about the phase change material effects on different solar collectors are discussed. This paper highlights the need for future research in develop of the solar water heater using materials for latent heat storage[6].

S. Sadhishkumar and Dr. T. Balusamy.et.al., Latent heat storage method is one of the most efficient ways of storing thermal energy. The latent heat storage method provides much higher storage density compared with the sensible heat storage method, with a smaller temperature difference between storing and releasing heat. The storage unit utilizes small cylinders, made of aluminium, filled with paraffin wax as the heat storage medium. In the morning, the storage tank is filled with water and this water is made to circulate through the solar collector heating panel. The water in the storage tank receives heat form the heating panel and transfers it to the PCM. The PCM undergoes a phase change by absorbing latent heat from the water. Experiments were performed in both charging and discharging processes. The storage tank is completely insulated to prevent loss of heat. The results show that, by using the PCM, efficiency of solar water heater is increased from 36.52% to 47.02%.

Atul Sharma C. R. Chen.et.al., Thermal energy storage has always been one of the most critical components in residential solar water heating applications. Solar energy is a dependent on time, energy source with a periodic character. The demands of the heat during day in residential house are also dependents on time. 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 way to cross the gap between the heat energy source, the sun, the system and the building. So, solar energy storage is essential in the solar water heating system. In this paper, an attempt has been taken to summarizes analyse of the solar water system incorporating with Phase Change Materials[1].

## IV. WORKING PRINCIPLE

The working principle used in our project is thermosiphon effect. The cold water is heated inside the solar collector. The hot water in the collector below is lighter than the old liquid in the tank above the collector. As soon as the lighter hot liquid rises, due to gravity the circulation of water starts. The copper tube and pipe are heated by solar energy from the sun. The copper have the high thermal conductivity. So it can conduct the heat to a medium level. The water is passed through the copper tube, in order to achieve the convection heat transfer (i.e. solid to liquid medium). Then the water is circulated through the copper tube and pipe by passive flow system.

The copper pipes are connected with the plastic insulated tank through the PVC pipe or the rubber hose pipes. The water capacity of the tank is 50 litres, which carries hot water at the top and cold water at bottom. The bottom level of cold water enters into the copper tubes and pipes are get heated by convection heat transfer, thus hot water reaches to the top of the tank. The water density of hot water is less when compared to the cold water, it can able to induce the passive flow in solar flat plate collector. The concentrating lenses are used to focus the radiation from the sun in to the copper sheet, which is coated with black colour and absorbs more heat energy.

The excessive heat energy in the tank is absorbed by PCM. The PCM are encapsulated by the air tight cover, immersed inside the water in the tank. The PCM absorb heat energy during the peak time, which melts and release the heat energy during the night time and also it maintain the constant temperature of the hot water .The PCM change from liquid to solid, when the heat energy liberates into the water. This repeated changes occurs (solid to liquid and liquid to solid) day by day.

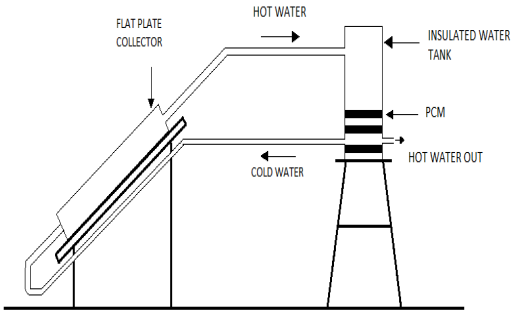



Fig 3 Outline of solar water heater with PCM

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## V. METHODOLOGY

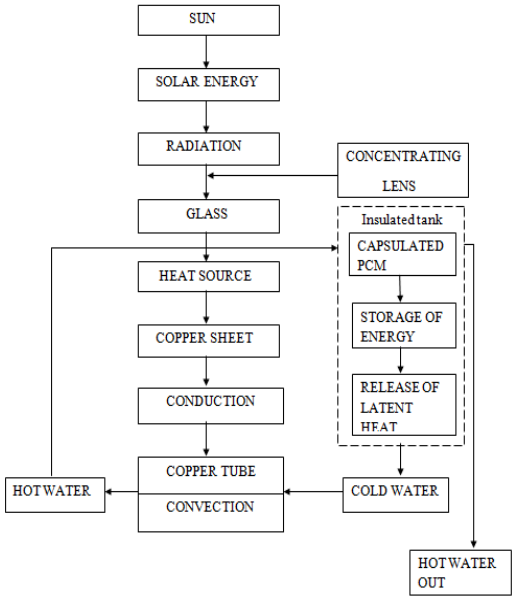



Fig 4 Methodology of solar water heater with PCM and concentrating lens

## VI. EXPERIMENTAL ANALYSIS

The test was conducted with 50 litres capacity water tank. The experiment were carried out at IFET college of Engineering (Villupuram), which dated on 13.03.2019 to 19.03.2019

### *A. Average Ambient Temperature:42°C*

TABLE 1 Temperature of water in the tank without PCM

| TIME(IST) | 13.03.2019 | 14.03.2019 | 15.03.2019 | 16.03.2019 | 17.03.2019 | 18.03.2019 | 19.03.2019 |
|---|---|---|---|---|---|---|---|
| 8.00am | 40 | 37 | 39 | 41 | 40 | 42 | 41 |
| 9.00am | 42 | 39 | 41 | 43 | 41 | 43 | 44 |
| 10.00am | 46 | 44 | 45 | 46 | 44 | 46 | 46 |
| 11.00am | 52 | 48 | 50 | 48 | 51 | 53 | 52 |
| 12.00pm | 54 | 50 | 53 | 55 | 52 | 56 | 53 |
| 1.00pm | 53 | 49 | 54 | 53 | 53 | 54 | 54 |
| 2.00pm | 51 | 48 | 53 | 51 | 51 | 52 | 51 |
| 3.00pm | 48 | 46 | 50 | 49 | 49 | 49 | 47 |
| 4.00pm | 47 | 44 | 49 | 46 | 49 | 47 | 44 |
| 5.00pm | 45 | 43 | 45 | 42 | 45 | 44 | 41 |
| 6.00pm | 41 | 38 | 43 | 39 | 41 | 37 | 36 |
| 7.00pm | 38 | 33 | 36 | 33 | 38 | 34 | 33 |
| 8.00pm | 35 | 32 | 33 | 32 | 34 | 33 | 32 |
| 9.00pm | 33 | 30 | 31 | 30 | 30 | 31 | 31 |
| 10.00pm | 32 | 29 | 30 | 29 | 29 | 29 | 30 |
| 11.00pm | 30 | 28 | 29 | 28 | 28 | 28 | 29 |
| 12.00am | 29 | 27 | 28 | 27 | 27 | 27 | 28 |

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The above reading of solar water heater without PCM have some changes in insulated tank for introducing PCM. Sodium thiosulphate pentahydrate used as a PCM, these are capsulated with (air tight cover or sphere shaped metal ) and immersed in insulated tank . The average value of ambient temperature are noted. The temperature of water and plate measured by thermometer. The experiment were carried out at IFET college of Engineering (Villupuram), which dated on 20.03.2019 to 26.03.2019

*B. Average Ambient Temperature: 42°C*

TABLE 2.
Temperature of water in the tank with PCM

| TIME(IST) | 20.03.2019 | 21.03.2019 | 22.03.2019 | 23.03.2019 | 24.03.2019 | 25.03.2019 | 26.03.2019 |
|---|---|---|---|---|---|---|---|
| 8.00am | 42 | 38 | 40 | 41 | 41 | 42 | 41 |
| 9.00am | 44 | 40 | 42 | 42 | 42 | 43 | 43 |
| 10.00am | 45 | 44 | 44 | 45 | 46 | 46 | 45 |
| 11.00am | 52 | 48 | 50 | 51 | 50 | 52 | 50 |
| 12.00pm | 53 | 49 | 52 | 53 | 51 | 54 | 51 |
| 1.00pm | 54 | 48 | 51 | 51 | 50 | 50 | 52 |
| 2.00pm | 54 | 47 | 50 | 50 | 49 | 49 | 50 |
| 3.00pm | 52 | 46 | 49 | 48 | 49 | 48 | 47 |
| 4.00pm | 50 | 44 | 49 | 47 | 48 | 47 | 46 |
| 5.00pm | 48 | 43 | 48 | 47 | 48 | 46 | 44 |
| 6.00pm | 46 | 43 | 43 | 42 | 45 | 43 | 48 |
| 7.00pm | 44 | 42 | 41 | 40 | 42 | 41 | 42 |
| 8.00pm | 43 | 41 | 40 | 38 | 39 | 42 | 39 |
| 9.00pm | 42 | 39 | 38 | 36 | 35 | 37 | 38 |
| 10.00pm | 41 | 38 | 37 | 35 | 35 | 36 | 36 |
| 11.00pm | 39 | 36 | 36 | 34 | 33 | 34 | 34 |
| 12.00am | 37 | 35 | 34 | 32 | 32 | 33 | 32 |

## VII. THEORETICAL ANALYSIS

The theoretical analysis to be done with mathematical equations to determine the theoretical values and to compare with the experimental result[6].

The various parameters which are associated with the SWH collector are as follows:

The instantaneous efficiency is given by

$$\eta_i = \frac{Q_{ui}}{I_s A_c} \quad (1)$$

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While the useful heat gain from the flat-plate is

| | |
|---|---|
| $Q_{ui} = A_C[S\text{-}U_L[T_{plate}\text{-}T_{ambient}] ]$ | (2) |

| | |
|---|---|
| $S = (T_\infty)_{av} I_t$ | (3) |

Where,
S=absorbed solar radiation (KWh/$m^2$/day)
$(T_\infty)_{av}$ = transmittivity of glass
$I_t$= incident radiation(KWh/$m^2$/day)
$A_c$= area of collector($m^2$)
The useful gain from the riser temperature is

| | |
|---|---|
| $q_u = \dot{m} C_p \Delta T$ | (4) |

While the instantaneous efficiency of the collector is the ratio between output and input power of the tubes configuration as follows:

| | |
|---|---|
| $\eta = \frac{q_u}{I_s A_c}$ | (5) |

The efficiency of solar water heater were calculated from the above formula about 60-70%.compared to normal solar water heater ,it has higher efficiency.

## VIII. RESULT AND DISCUSSIONS

The experimental study was conducted during the month of March 2019. The passive solar water heating system tested to investigate its performance in terms of the water heating through solar energy with PCM and without PCM.
We took seven day in testing of the solar water heater with PCM and without PCM and took readings at different timings in a day from morning to noon. Thus the efficiency taken with PCM and without PCM, where performance is improved during day time by concentrating lens and hot water is obtained and the temperature is maintained during night time. The below graph shows the average value of the solar water heater with PCM and without PCM.

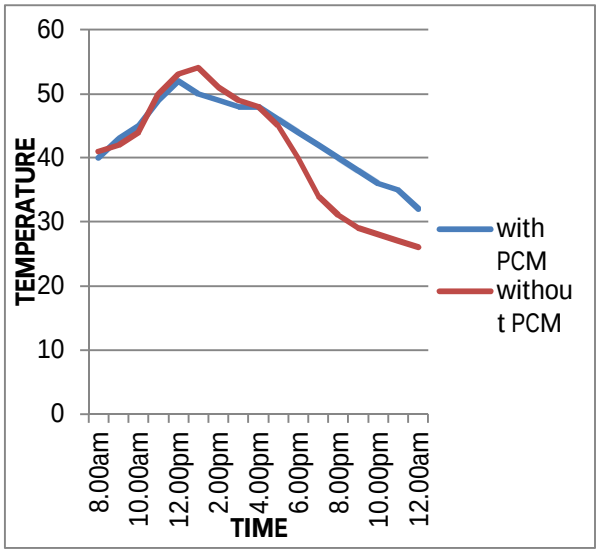



Figure 4. Comparison of temperature(°C) with PCM and without PCM

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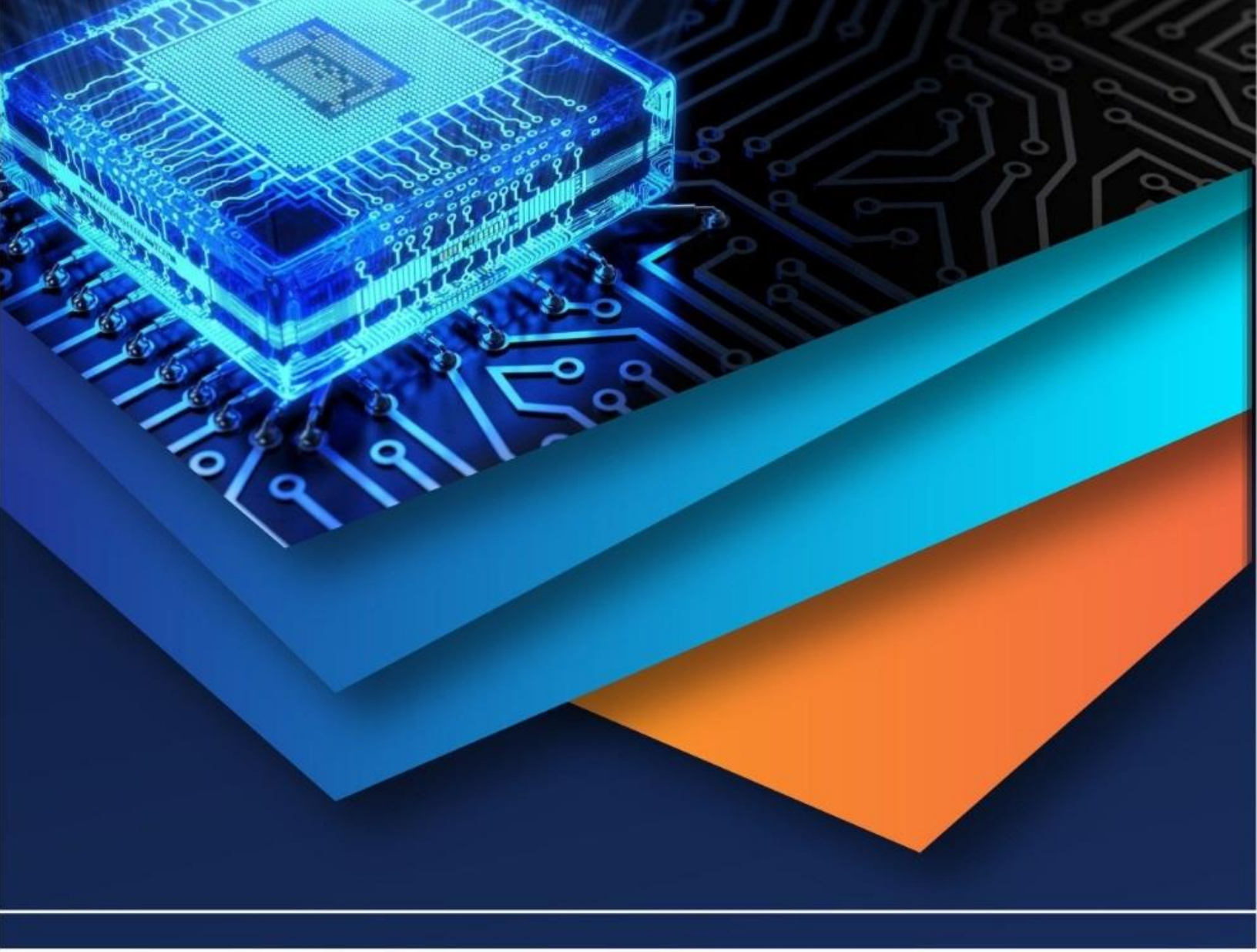
## IX. CONCLUSION

The use of PCM in solar water heater helps to decreases cooling rate of water, thus it enhance the maximum utilization of solar energy and hence improves efficiency of system. Heat capacity of solar flat plate collector increases at reduced starting heat rate because PCM take heat energy to get heated. As PCM based solar water collector store maximum light or heat energy, it reduces the size of tank and hence can decrease the cost of Solar Water collector. The PCM is used in solar water heater helps to reduce cooling rate of water, thus it helps to give the maximum utilization of solar heat energy and hence increases the efficiency of system. In future this project will also help to find the suitable PCM and provide the various designs for solar water heating systems to store the thermal energy from sun.

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