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# A STUDY ON PERFORMANCE OF SOLAR WATER HEATER USING LAURIC ACID-WATER AS THERMAL STORAGE SYSTEM

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***ABSTRACT***

***The energy consumption in the world is increasing greatly owing to the growing population, and to the increasing energy consumption per capita. The availability of the fossil fuels is fast declining, and the price of the fossil fuels is increasing rapidly, hence there is a great motivation to use renewable energy sources such as solar energy. Domestic water heating which constitutes a significant share of residential energy consumption is an excellent application for utilizing solar energy. In this work performance test is carried out using Phase Changing Material and water as thermal storage system. The system consists of two simultaneously functioning heat absorbing units. One of them is a solar water heater and the other a thermal energy storage unit with Lauric acid as phase changing material (PCM). Effect of adding Aluminium powder to PCM is also studied in this experiment. The performance of the system will be analysed with various modes of closed modes of charging and discharging trials. Experiments are conducted for different void fractions and mass flow rates of heat transfer fluid. The results have shown that the charging and discharging temperature will be higher by adding small quantity of Aluminium powder to PCM. Also hot water can be stored and discharged for a longer duration there by increasing the performance of solar water heater***.

***KEYWORDS****:* ***Phase Changing Material, Heat Transfer Fluid, Lauric Acid, Aluminium Powder, Solar Water Heater, Thermal Energy Storage***

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**Original Article**

## INTRODUCTION

Energy demand is constantly increasing all over the world day by day. World is mainly depending on fossil fuels to cope up with these energy needs, which results in emission of green house gases and other pollutants. Global warming and environmental pollution are the outcome of these emissions.

There is a tremendous research going on in the entire world to search alternative sources. The most abundant source of energy to be found on the planet is solar energy. In comparison to other energy sources derived from oil, coal and nuclear reaction, solar energy is much cleaner and also far more abundant. Solar thermal energy finds its simplest application in the form of solar water heating, which in itself has enormous potential for reducing dependence on conventional fuels in the domestic sector. Since the availability of solar energy is dependent on various conditions such as time, weather, latitude and the fluctuating demand for electricity over long periods the originally harnessed energy needs to be stored. In addition to this, the demand for energy is also time based which means that people's need for energy varies from season to season and from day to night. It is this cyclic nature of both supply and demand energy that has created the need for energy storage. Solar energy can be stored as thermal energy or electricity, but thermal energy storage is considered the more economical method [1].

By choosing a suitable phase change material solar energy can be stored in the form of latent heat. PCM's absorb, store and release heat when they change state, such as from solid to liquid. The heat stored by the PCM can be used to heat water after sunset[2]. It is found that the use of phase change materials is an effective way of storing thermal energy and has an advantage of high energy storage density [3]. In a study it was found that addition of high conductivity material to PCM improved its performance [4].

In this study Lauric acid along with Aluminium powder is used as phase change material. In this work tests will be carried out on solar water heater with PCM and water as storage material. This system consists of two simultaneously functioning heat absorbing units. One of them is solar water heater(SWH) and the other one is thermal energy storage(TES) unit consisting phase changing material in spherical capsules[5].

The objective of this study is to know the effect of phase changing material in thermal storage system and its void fraction on the performance of solar water heater. Experiments are conducted with both natural and forced circulation. The performance of the system is analyzed with various modes of charging and discharging trials. Experiments are also conducted for various fractions of Aluminium powder in phase change material and its effect on the performance of solar water heater.

## EXPERIMENTATION AND METHODOLOGY

- **Experimental Set Up**

Schematic diagram of the experimental set up is shown in figure 1. The solar flat plate collector has area of about 2.3m$^2$, located on the leveled ground with a tilt angle of 20$^0$. The solar water heater has single glazed, toughened glass cover of 4mm thickness and black painted absorber plates which are connected to the main water supply and hot water storage tank through a set of valves enabling open loop and closed loop operation. The TES tank has a capacity of about 84 liters, with an internal diameter of 440mm and a height of 550mm. It houses the PCM capsules and allows for heat transfer between the capsules and HTF. The tank is insulated with 75mm of glass wool and is provided with an Aluminium cladding sheet. The PCM will be capsulated in steel cylinders of internal diameter 0.1003m [6]. The cylinders will be packed in layers one over other, with every layer separated by a wire mesh.

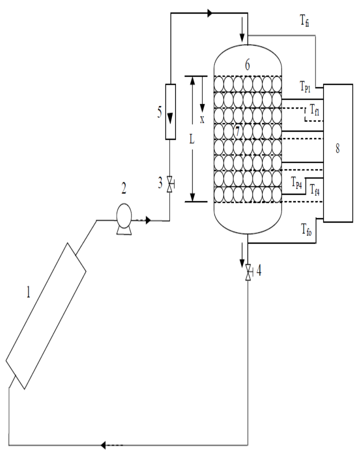


**Figure 1: Schematic of Experimental Setup**

1. Solar flat plate collector; 2. Pump; 3 & 4.Flow control valves; 5. Flow meter; 6. TES tank; 7. PCM capsules; 8.Temperature sensors

The flow rate of the HTF through the system can be carried using a valve. The PCM used is Lauric acid with a melting range of 45-50$^0$C and water is used as both the HTF and the SHS material. The temperatures of PCM and HTF will be continuously recorded at different locations using temperature sensors. Solar radiation is measured using Pyranometer.

- **Methodology**

The temperature readings will be continuously recorded at different locations inside the storage tank and also the solar radiation will be monitored for every 30 minute interval with the help of radiation sensor, temperature sensor. Duration of charging process is from morning 9:00 to 4:00pm and discharging process from 4:00 to 7:00 pm. During the discharge process water in the TES shell will be withdrawn batch wise.

- **Procedure**

The experiment has been carried out in 2 phase: storage performance with closed loop system (charging) and storage performance with open loop system (discharging). The water from the overhead tank enters the hot water storage tank and then flows in to the flat plate collector. Water gets heated in the risers of the flat plate collector and its density will decrease, the lighter density water move up and is stored in the hot water storage tank and the cycle repeats. The investigation includes a set of day long experiments representing different scenarios. Experiments will be conducted for both natural and forced circulation.

During the charging process the HTF was circulated through the TES tank and the solar collector unit continuously. The HTF absorbs solar energy sensibly and exchanges this heat with the PCM in the PCM storage tank. The PCM slowly gets heated, sensibly first until it reaches its melting temperature. As the charging proceeds energy storage as latent heat is achieved as Lauric acid melts at a temperature of around 45$^0$C. The charging process continues till the PCM and the HTF attain thermal equilibrium. Temperatures of the PCM and HTF will be recorded at an interval of 30 minutes.

The discharging process used is termed as batch wise process. In this method a certain quantity of hot water is withdrawn from the tank and the tank is refilled with cold water to maintain a constant amount of water in tank. This is then repeated for intervals of 30 minutes during which transfer of energy from the PCM would have occurred. This procedure is continued till PCM reaches a temperature of 40$^0$C.

## RESULTS AND DISCUSSIONS

The objective of the study is to identify the best combination of PCM and HTF mixture, void fraction. Results were recorded by varying void fraction and by adding additives to PCM.

The experiment was conducted for six different combinations of PCM-HTF namely, (i) Lauric acid –HTF for void fraction(75%), (ii) Lauric acid- HTF for void fraction(85%), (iii) Lauric acid- HTF for void fraction (90%),(iv) 10g Aluminium powder mixed with Lauric acid- HTF for void fraction(75%), (v) 10g Aluminium powder mixed with Lauric acid- HTF for void fraction(85%),(vi) 10g Aluminium powder mixed with Lauric acid- HTF for void fraction(90%). Experiments were conducted for ten days each for the above combinations. However, in order to evaluate relative merits of each combination, the performance is required to be compared for same or similar solar radiation. Therefore it is very essential to identify one day for each combination on which solar radiation were almost same. Solar radiation details for all days were compared and days on which solar radiation were almost same were chosen.

- **Charging and Discharging of HTF in Solar Water Heater**

The variation of charging temperature of water in conventional solar water heater is shown in figure 2 and discharging temperature in figure 3.

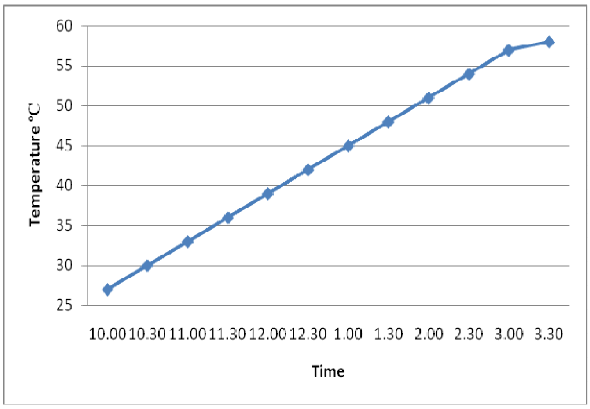


**Figure 2: Variation of Charging Temperature of Water**

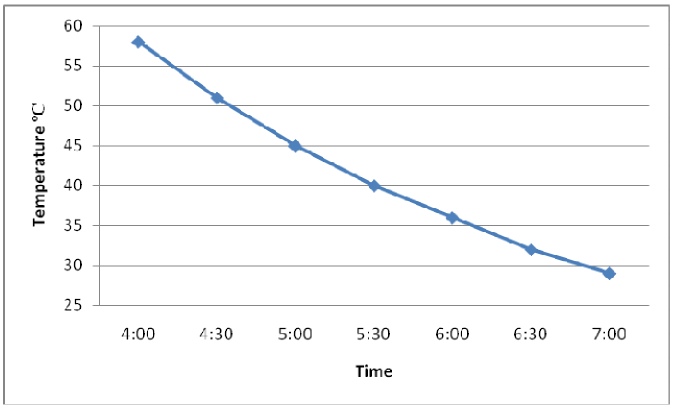


**Figure 3: Variation of Discharging Temperature of Water**

- **Charging and Discharging in Case of Spheres Filled Only with Lauric Acid**

The charging temperature in case of spheres filled only with Lauric acid is shown in figure 4 and the discharging temperature is shown if figure 5. The Y axis represents the temperature of HTF fluid in degree Celsius. The X axis represents time in hours. The readings were noted every half an hour. In the discharge process every half an hour around 15L of hot water is discharged and same amount of cold water is added into the tank to make up for the removal of water.

It can be observed from the figures that the temperature associated with the heat transfer fluid is high for 75% void fraction. This could be attributed to absorption of more amount of heat energy due to increased surface area by steel spheres. Also the discharging temperature associated with 40 steel spheres is high due to which hot water is available for a longer period of time. With 75% void fraction more amount of heat can be stored compared to 85% and 90% void fraction.

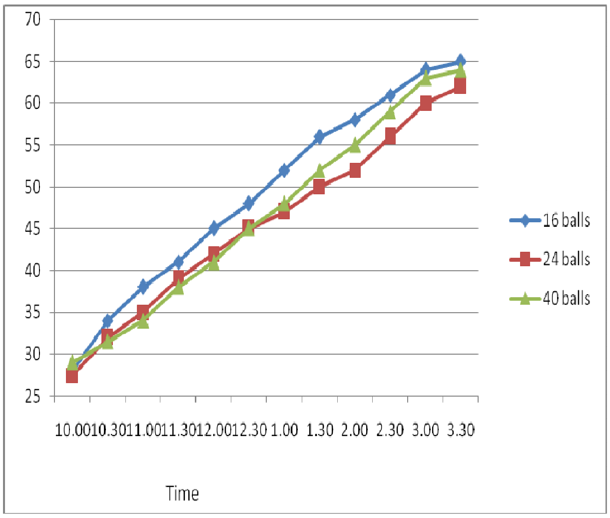


**Figure 4: Variation of Charging Temperature with Lauric Acid for Different void Fractions**

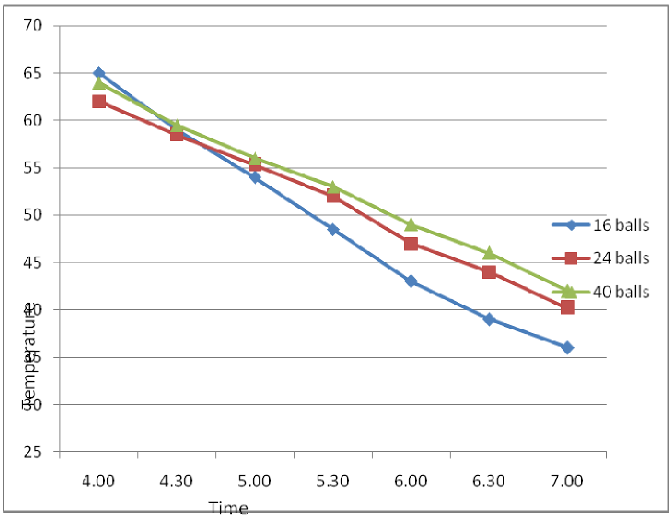


**Figure 5: Variation of Discharging Temperature with Lauric Acid for Different Void Fractions**

- **Charging and Discharging in Case of Spheres Filled with Lauric Acid and 10g Aluminium Powder**

The charging temperature in case of spheres filled with Lauric acid and Aluminium powder is shown in figure 6 and the discharging temperature is shown if figure 7. The Y axis represents the temperature of HTF fluid in degree Celsius. The X axis represents time in hours. The readings were noted every half an hour. It can be observed that the charging and discharging temperatures obtained in case of spheres filled with Aluminium powder and lauric acid is higher than spheres with only Lauric acid. Hence addition of Aluminium powder enhances the thermal conductivity of Lauric acid.

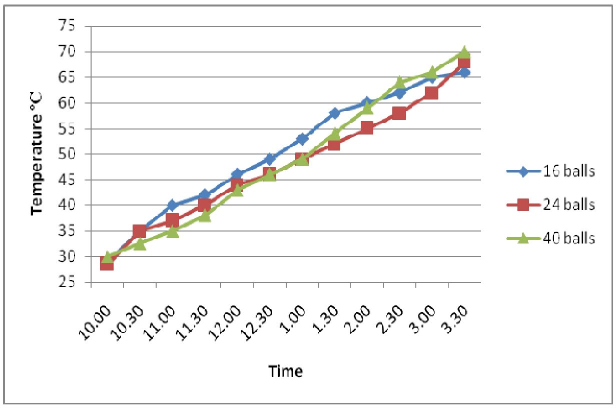


**Figure 6: Variation of Charging Temperature with Lauric acid and Aluminium Powder for Different Void Fractions**

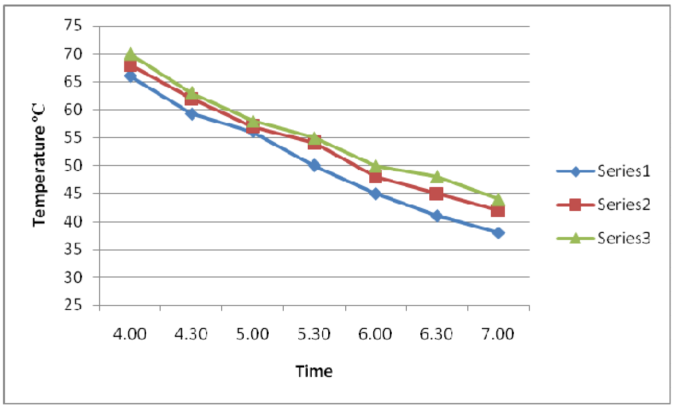


**Figure 7: Variation of Discharging Temperature with and Lauric Acid and Alulinium Powder for different Void Fractions**

## VALIDATION

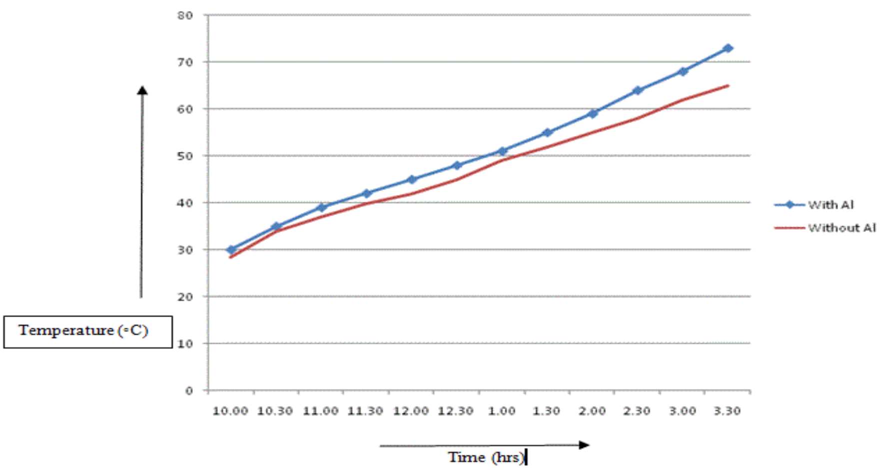


**Figure 8**

Various experiments conducted for charging with Lauric acid and Al powder filled in 16, 24 and 40 balls made of steel. The results have shown beneficial effect on 24 balls made of steel. Hence we have considered with aluminium powder shows effective results comparatively without aluminium.

## CONCLUSIONS

In this work, experiments were carried out on solar water heater using PCM material for various void fractions, and also by adding 10 gram Aluminium powder to Lauric acid to enhance its performance. Based on the results the following conclusions could be drawn.

It is found out from the experiments that the charging and discharging temperature will be higher when we add small quantity of Aluminium powder to Lauric acid. Hot water can be stored and discharged for a longer duration because the charging temperature is higher for Lauric acid with Aluminium powder in it. The performance of solar water heater is enhanced when 40 steel balls i.e 75% void fraction, are used compared to 16 steel balls and 24 steel balls. The performance is enhanced when 10 gram Aluminium powder is added to Lauric acid filled spheres, when compared to only Lauric acid added spheres. Lauric acid along with Aluminium powder can be easily used as phase changing material in solar water heater to enchance its performance.

***REFERENCES***


1. *Sharma N. (1989). "Review on thermal energy storage with phase change materials and applications." International Journal of Energy Research,13,253-265*
2. *Meenakshi Reddy & Prasad (2010). "Thermal Energy Storage System using Phase change materials." Constant Heat Source, 67-85.*
3. *Quanying Yan, (2011). "Experimental Study on the Influence of Additives on thermal properties of Paraffin mixtures." IEEE#978-1-4244-6255-1.*
4. *Vijay Padmaraju S A, Vighnesh M & Nallusamy N. (2005). "Comparative study of sensible and latent heat storage systems integrated with solar water heating unit."*
5. *Amrit Om Nayak,M.Gowtham,Vinod R and Rakumar. (2011). "Analysis of PCM material in thermal energy storage system." International Journal of Environmental Science and Development,2,6.*
6. *Alkilani Mahmud, Sopian K, Alghoul M A and Mat Sohif (2009). "Using Paraffin wax- Aluminium compound as a thermal storage material in a solar heater." ARPN Journal of Engineering and Applied Sciences,4,10.*