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A Review on Phase Change Material in TES System

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***Abstract*: The objective of an experimental study is to investigate the thermal characteristics of charging and discharge processes of thermal energy storage system using Phase change materials. Performance evaluations of experimental results during charging and discharging processes of paraffin wax and fatty acid have discussed. PCM play a substantial role in energy storage for solar thermal applications and renewable energy sources integration. Considerable research has been carried out for energy storage to achieve better efficiency and performance. PCMs like $MgCl_2.6H_2O$, $Mg(NO_3)_2.6H_2O$, $CaCl_2.6H_2O$, Paraffin wax, $CH_3(CH_2).16CH_3$, $CH_3(CH_2).11OH$ have proved successfully in solar thermal and thermo-electrical applications. This work reviewed and unit the trends of PCMs in energy efficient thermal energy storage systems. Charging & discharging performance analysis of PCM -1(Paraffin Wax) PCM -2 (Organic fatty acid).**

Index Terms: Phase change Materials (PCMs), Thermal Energy Storage System (TES), Organic PCM, Inorganic PCM, Thermo Physical Properties discharging and charging period.

Introduction: Phase change materials are substances which interact with different conditions of environment and change their property by showing different phases.the phases refer to the transition of substance from one phase to another (solid to liquid, liquid to gas or vice versa). The change in physical characteristics is accompanied with absorbing or releasing energy i.e., heat. PCMs can be formed from different constituent particles so different materials. The thermal energy storage (TES) can be defined as the temporary storage of thermal energy at high or low temperatures. The TES is not a new concept, and at has been used for centuries. Energy storage can reduce the time or rate mismatch between energy supply & demand and it plays an important role in energy conservation .Energy storage improves performance of energy systems by smoothing supply and increasing reliability. For example, storage would improve the performance of a power generating plant by load leveling. The higher efficiency would lead to energy conservation and improve cost effectiveness. Some of the renewable energy sources can only provide energy intermittently.

Classification of PCMs:

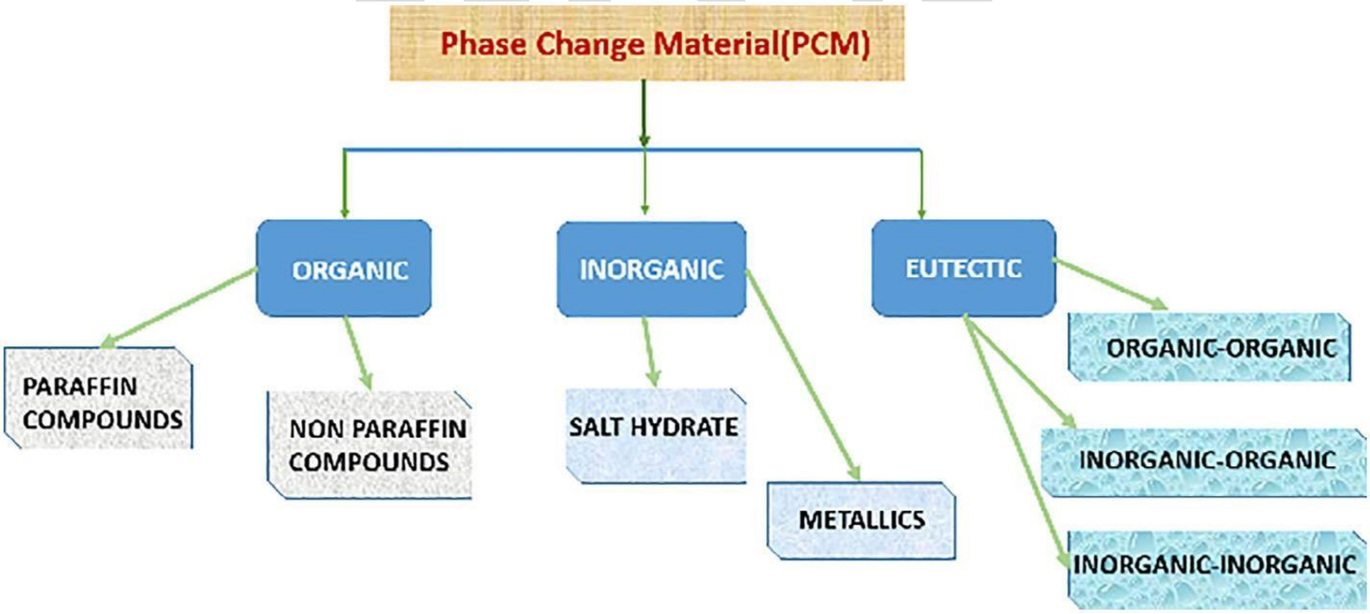

Fig.: Types of PCMs

Setup Components:

Heat Source Tank: Heat source tank is the key component of thermal energy storage system where the HTF gets heated up through electric heaters which are connected inside the tank. This tank is insulated using PUF and enclosed externally with gasket and sealing. This tank is of 50 L capacity and equipped with two 3KW electric heaters with auto cutoff.

PCM Tanks: There are three PCM Tanks within the system filled with paraffin wax, Fatty acid and cascading of both. Each tank is filled with 5kg of PCM and insulated with 5cm of PUF enclosed with gasket. Each tank is equipped with heat exchanger made of copper to transfer the heat from HTF to PCM during charging and to regain heat during discharging by sending cold water in to the PCM tanks.

Used HTF/Cold HTF Storage: These two 120 liters tanks are placed at the bottom of the system to store the used HTF and reuse that once it attains room temperature again. The product is designed for laboratory purpose, to avoid refilling the tank over and again the system comes with portable storage tanks within the system frame to perform experiments hassle free.

Frame: The role of frame is to support components such as tanks, storage units, pump, control unit, sensors and piping. Apart from mechanical support the system has to be mobile to operate and maintain, the frame comes with movable wheels making it simpler and robust.

Control Unit: The system comes with 17 different sensors for temperature and flow rate- the control unit has different temperature and flow rate display units with switches to control different apparatus like heaters, pump and to measure flow rate.

Literature Review:

Bhupendra Gupta et al. (2021) In their research work has has carried out for energy storage to achieve better efficiency and performance. Phase change Materials (PCMs) available in various temperature range have proved efficient in solar thermal energy storage situations.Incorporating PCMs in solar applications resulted in enhancement in the order of 12 to 87% in thermal efficiencies of the systems. Also this work reviewed and unites the trends of PCMs in energy efficient solar energy storage systems.

Khandagre et al. (2021) research work aims to improve the performance (productivity of fresh water) using $Mg_2\,SO_4.7H_2O$ as phase change material (PCM). For experimentation, two identical double slope solar stills (basin area of 0.5×0.5 m2) were designed, fabricated and tested for freshwater productivity. One is solar still (without PCM) and second with phase change material. The results obtained indicate that daily distillate for solar still with Magnesium sulfate heptahydrate is higher as compared to solar still without PCM. The convective heat transfer coefficient increases during the discharging period of PCM.

Dr. Azhar Hussain et al. (2020) in this research work the paraffin graphite composite is formulated by the dispersion of graphite in paraffin wax above the melting temperature of the paraffin wax. So, after dispersion in paraffin wax, thermal conductivity is measured. SEM techniques are applied to determine the alignment of graphite in paraffin while thermal conductivity is measured by using Fourier's law. Results showed that graphite not only enhances thermal conductivity of paraffin graphite composites but also due to alignment of graphite thermal conductivity further improved.

Dr.B.Kanimozhiet al. (2017) In this research work the charging process was carried out by applying HTF at 76^0C with a different flow rate of 6 kg/min, 4kg/min, and 2kg/min to the PCM storage tank. During the charging process the HTF is circulated continuously through the PCM storage tank. The Performance evaluations of experimental results during charging and discharging processes of paraffin wax have discussed in which heat absorption and heat rejection have been calculated with various flow rate. Analysis the Phase Change Material is the latent heat storage materials.**Apurv Yadav et.al.(2020)** It's concerned with the improvement of performance of a solar thermal storage system employing phase change material (PCM) with the addition of nano additives. The results showed that dispersion of 0.5 wt. % of mesoporous carbon in the PCM was able to enhance the heat transfer rate. A fourfold increase in the thermal conductivity of the nano composites was observed with the addition of nano particles. Charging and discharging rate of a solar thermal storage system could be increased by employing these nano enhanced PCM.

Y.S. Prasanna et al.(2020) In the present decade, energy demand is one of the most challenging issues being faced throughout theworld. To overcome the problems in the high energy production, the recent advances in nanotechnology,with a huge range of nano structured materials have become all the rage for energy storage applications. Agreat number of devices have been developed in recent decades with the advancement of nano science. Inthe concept of renewable energy resources, Solar Energy can be referred to as the ''elixir of power production"throughout the world. Extensive research is being carried out for distinguished Nano materialson energy storage applications by researchers and scientists to produce an efficient power absorptionand storage material with high thermal conductivity and high corrosion resistance. In this paper, reviewingthe concepts of nanotechnology in solar energy applications is made excessively focusing on PCM,Nano fluids, and Nano composites. Also by considering several other important factors in energy storageapplications a statistical/graphical approach is presented for a better understanding by taking differentresearch and review articles. This paper extensively would give researchers ease in the selection of materialfor energy storage applications

A. S.N. Husain et al.(**2017**) It's carried out on two different setups of double slope single basin solar still with and without thermal energy storage by phase change material. He used paraffin wax as a phase change material the distillate production is said to be increased to 10-25% with PCM.

Dr. M. Ravi Kumar et. al.(**2017**) In thisstudy the three types of investigation carryout for the setup: (1) Only Wastewater poured into the chamber, (2) Black stones placed over the bottom of the plate, (3) Using the Paraffin wax used as a phase change material. The mixture of titanium oxide and paraffin wax was poured into the copper tube and placed over the surface plate. Solar energy stored large quantity in day period lesser in night time by the paraffin wax liberates its stored heat. The absorbed heat energy cannot escape in the chamber. Because the double glass solar still fully insulated by Polyurethane Foam. In this experiment gives the water production rate at different session.

B. K. Patil and S. dambal et. al.(2016)In this work was conducted on a double slope single basin solar still using Phase changing materials like (paraffin wax) and Sensible heat storage elements like (black pebbles) A double slope single basin solar still with area of 0.7m2 was fabricated with Aluminium sheet metal and experiment is carried out in open environment conditions. An Aluminium tray of 0.40m2 is placed inside the still giving 10cm gap. Remaining set of readings (with PCM and SHSE) were compared with standard readings and analysis is done by showing set of graphs and tables. Thus the percentage productivity observed in case of Paraffin wax and black coated tray is 30%, black pebbles and black coated tray is 18%, Paraffin wax and black pebbles is 13%.

G. Rajasekhar and M. Eswaramoorthyet al. (**2015**) In this paper about the performance evaluation of single slope solar still integrated with nano-composite phase change materials and compare with the experimental results of with and without phase change materials. Photographic view of solar still integrated with thermal energy storage. A solar still with 1 m2 surface area is developed with non-selective coating of absorber sheet with the provision of thermal energy storage materials. It was found that from the experimental studies that nanomaterial (Al_2O_3) dispersed in paraffin wax is giving better cumulative yield of distillate than paraffin wax alone and without paraffin wax thermal storage. The daily efficiency of the solar still is computed for solar still with nano-composite phase change materials is 45% and solar still paraffin wax alone thermal storage is 40% and solar still without any thermal storage is 38%.

M. T. Chaichan and H. A. Kazemet al.[**2015**] In the presents study of heat transfer enhancement of paraffin wax existing in single slope solar distiller base and sides. Aluminium powder was added to paraffin wax to enhance its thermal conductivity. Three distillers fabricated; one without any modification, the second took the advantage of placing PCM inside it. The third one used PCM with aluminium powder to enhance its thermal conductivity. The results show that aluminium powder ameliorated phase change materials exhibit enhanced thermal conductivity in comparison to the base material. Adding aluminium powder to PCM, increased distiller productivity as well as increased distillation time.

Hemin Thakkar et al.[**2014**] In this study on solar still Integrated with Nano-composites with and without use of paraffin wax as a Phase change material. For the evaluation of performance, three identical 1 square meter area solar stills have used. First solar still integrated with Nano-composites and PCM, second with only Nano-composites and third is without Nano-composites and PCM. For the preparation of Nano-composites aluminum oxide is used and coated on the surface of the Absorber plate. It has found that, solar still integrated Nano-composites found 92% more productive compared with alone solar still and only Nano-composites integrated solar still is 106 % more productive compared with alone solar still.

Table 1: Thermo physical Properties of paraffin

Properties		**Paraffin wax**
Melting point		58 ºC
Latent Heat		200-210 kJ/kg
Density		920 kg /m^3
Heat capacity	Solid	2 kJ/kg· K
	Liquid	2.5 kJ/kg· K
Thermal conductivity		0.2 -1.7 W/m· K.

Conclusion: Solar thermal energy storage applications facing problems of low density and storing capacity. Type of PCM and their thermo-physical properties very much affects the outcome. Different types of organic and non-organic PCMs have been reviewed in this article suitable for specific situations. The present review work will help researchers and practitioners in selection and utilization of PCMs for different solar thermal energy storage system applications.

The following conclusions drawn from this study:

- Temperature range is very important criteria to select the PCM type.
- Thermo-physical properties must be considered before putting use of any PCM.
- PCMs proved their role to enhance performance of the system either solar thermal or solar PV system heat transfer applications.
- In the fabricated storage tank heat can transfer from the HTF to the PCM as well as from the PCM to the HTF during charging and discharging processes.

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