Comparative Study of Phase Change Material For Enhancement of Thermal Storage In Solar Water Heating

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Abstract- *The utilization of abundantly available solar energy for domestic and industrial applications is hindered because of its intermittent nature. Thus attempt is made to utilize this energy when it is not available. The aim of this experimentation is to study and decide the ideal PCM amongst the five PCMs and their feasibility of storing solar energy and using ability of this energy to heat water for domestic purposes during night time. Thus the availability of hot water will extend its limits to the span of entire day. The system consists of two heat-absorbing elements. One of them is a solar water heater and the other a heat storage element consisting of phase change material (paraffin wax, OM46, OM48, OM53, OM55). The water heater functions normally and supplies hot water during the day. The storage element stores the heat in PCMs during the day and supplies hot water during the night. The storage element utilizes small spheres, made of HDPE, filled with PCM as the heat storage medium. The PCM undergoes a phase change by absorbing latent heat, excess heat being stored as sensible heat. The mild steel water tank has a capacity of about 100 liters, it houses 26% of PCM inside the square tank having length 90 cm and allows for heat transfer between the surface and the water. Experiment results show with using PCM cooling rate during the night decrease & efficiency and heat storage capacity increases.*

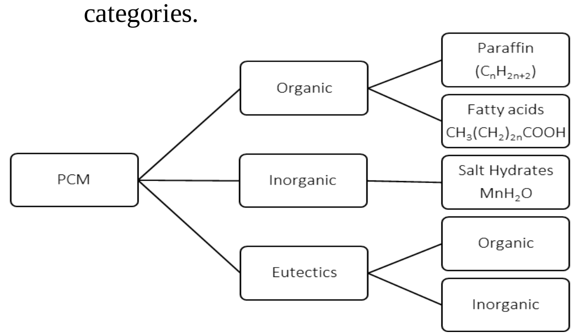
Keywords- phase change material (PCM); latent heat; paraffin; High density polymer (HDPE), thermal energy storage

I. INTRODUCTION

A phase change material (PCM) is a substance with a high heat of fusion which melting and solidifying at a certain temperature is capable of slowing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice-versa.The phase change material (PCM) have any property of changing its phase according to the change in temperature. For e.g. when the temperature rises the PCM absorbs heat. When the temperature drops, the PCM solidifies and the heat is emitted. And during the phase changing process, the temperature of the material remains constant. Thus the name itself suggests the working of the mechanism of the PCM. The cubes are an illustrative example of phase change material (PCM) material work, as they melt in a drink. They absorb heat from the environment as they solidify in a freezer compartment. They release heat into the air. And the most important thing here is, during the change from the solid to the liquid phase and vice versa. The temperature remains the constant a zero degree Celsius. This hidden heat storage in the phase change is termed as latent heat.

The PCM are classified under three categories:

- Organic PCM are naturally available PCM's
- Inorganic PCM are chemically generated PCM's
- And Eutectics are the mixture of the above two categories.



Applications of PCM providing energy efficient solutions for many industries include:

- Insulation for Building and Piping Products
- Biopharmaceutical Transportation
- Telecommunications and Heat Sinks
- Hot and Cold Storage
- Food / Poultry / Milk Products Transportation
- Boiler and Hot Water Systems Industry looking to exploit off peak Electricity Tariffs / Reducing Chilling Equipment.

II. EXPERIMENTAL SETUP

Pluss savE® Phase Change Materials (PCM) are organic or inorganic chemical compounds that have large amount of heat energy stored in the form of latent heat which is absorbed or released when the materials change state from solid to liquid or liquid to solid. The PCM retains its latent heat without any change in physical or chemical properties over thousands of cycles. Various specific temperature savE® PCM's are commercially available (-33oC to +89oC) depending upon the applications. [1]

Encapsulation of the PCMs:

Pluss® pioneered the use of HDPE panels as encapsulation for PCMs in India. The calculations for total heat transfer across thin membranes show that HDPE/ PP is as good as aluminium, stainless steel, etc. Pluss® encapsulations are thin enough to give good overall heat transfer coefficient and provide good mechanical strength. Pluss savE® - OM 46, OM 48, OM 50, OM 55 have been selected according to the required temperature range of 45-60 oC. savE® PCMs are a range organic chemical based PCM having nominal melting temperature of 46oC. They store thermal energy as latent heat in its crystalline form. On changing phase, this latent heat is released or absorbed, allowing the ambient temperature within the system to be maintained. savE® PCMs are constituted of the right mix of various salts, additives and nucleating agents allowing equilibrium between solid and liquid phases to be attained at the melting point. These are free flowing in molten state and can be encapsulated in various forms.

Table 1: Properties of savE® OM 46

Property	Value
Melting Temp (°C)	46.0
Freezing Temp (°C)	47.0
Latent Heat (kJ/kg)	250
Liquid Density (kg/m3)	880
Solid Density (kg/m3)	930
Liquid Specific Heat (kJ/kgK)	NA
Solid Specific Heat (kJ/kgK)	NA
Liquid Thermal Conductivity (W/mK)	0.10
Solid Thermal Conductivity (W/mK)	0.20

Table 2: Properties of savE® OM 48

Property	Value
Melting Temp (°C)	48.0
Freezing Temp (°C)	46.0
Latent Heat (kJ/kg)	275
Liquid Density (kg/m3)	875
Solid Density (kg/m3)	900
Liquid Specific Heat (kJ/kgK)	NA
Solid Specific Heat (kJ/kgK)	NA
Liquid Thermal Conductivity (W/mK)	0.12
Solid Thermal Conductivity (W/mK)	0.20

Table 3: Properties of savE® OM 50

Property	Value
Melting Temp (°C)	50.3
Freezing Temp (°C)	50
Latent Heat (kJ/kg)	250
Liquid Density (kg/m3)	NA
Solid Density (kg/m3)	850
Liquid Specific Heat (kJ/kgK)	3.05
Solid Specific Heat (kJ/kgK)	NA
Liquid Thermal Conductivity (W/mK)	0.14
Solid Thermal Conductivity (W/mK)	0.21

Table 4: Properties of savE® OM 55

Property	Value
Melting Temp (°C)	57.0
Freezing Temp (°C)	55.0
Latent Heat (kJ/kg)	210
Liquid Density (kg/m3)	NA
Solid Density (kg/m3)	840
Liquid Specific Heat (kJ/kgK)	3.05
Solid Specific Heat (kJ/kgK)	NA
Liquid Thermal Conductivity (W/mK)	0.1
Solid Thermal Conductivity (W/mK)	0.16

26% of volume occupied by the PCM gives the optimum results. Hence, for the 100 litre storage tank 26 litres volume is occupied by the PCM. [4] The respective masses for the selected PCMs are as follows:

Table 5: Data according to 100 litres tank

Name of PCM	Density (kg/m^3)	Volume (litres)	Calculated mass (kg)
OM 46	930	26	24.18
OM 48	900	26	23.4
OM 50	850	26	22.1
OM 55	840	26	21.84

Design of the water heater:

The heater consists of a rectangular galvanised iron tank of 9 cm depth and 1 m2 exposed surface area, filled with water. The top surface of the tank, which works as the absorber plate, is coated with ordinary black paint.[7] A glass cover 3 mm thick is placed over the black surface of the tank with an air gap of 2.5 cm. The whole system is fixed at an angle of 45° to the horizontal and faces south to collect maximum solar horizontal and faces south to collect maximum solar radiations in Lonavala.

The criterion for selection of the PCM is discussed by the authors. On that basis, we have selected paraffin wax as the PCM material. The PCM-filled metallic capsules are placed at the bottom of the tank forming a 4 cm thick layer parallel to the absorbing plate. Water can flow through the space between the outer walls of the capsules. The use of these capsules is necessitated because of the inclination of the system. In the absence of capsules, the melted layer of the PCM would not have been parallel to the absorbing plate. This would have resulted in a much lower heat transfer between the water storage system and the PCM storage system. The metallic capsules have the added advantage of increasing the heat transfer between the PCM and water. The bottom and the sides of the heater are insulated with a 5 cm thick layer of fibre-glass insulation. Hot water is taken out from the top of the heater by opening a gate valve at the inlet pipe at the bottom and letting in water at ambient temperature.

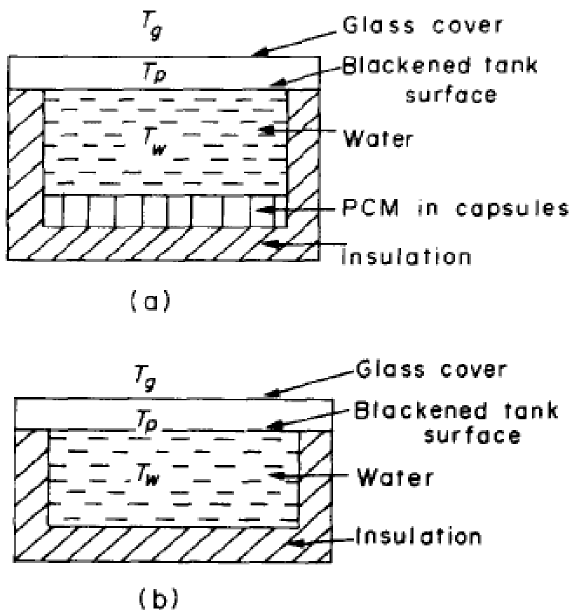


Fig: Schematic diagram of built-in storage type water heater.

III. CONCLUSION

The fabrication of the proposed design is underway. From the referred literature it is observed that water heaters with PCM storage at the bottom are more suitable for hot water requirements during off-sunshine hours. [9] PCM storage without night insulation is almost as effective as conventional built-in storage type water heaters with night insulation. For day-time hot water requirement, the PCM layered system is not recommended.

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