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Analysis of Various Phase Change Materials and its Application for Solar Water Thermal Storage System

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Abstract - ***This paper is aimed at analyzing the behavior of a four phase change materials as a part of thermal energy storage system. The analysis is carried out using one organic and three inorganic phase change materials including Paraffin wax, Sodium sulphate decahydrate, Magnessium nitrate hexahydrate and Nickel nitrate Hexahydrate respectively.***

As solar energy is periodic and irregular in nature it gives limitations for its usage. Even in locations with pleasing solar radiation gives only few hours of high radiant incidence per day.

Further in this paper solar water heating system using phase change material is described schematically. Sodium sulphate decahydrate can be used for solar water thermal storage system as application of PCM which can be useful during off sunshine hours.

Key Words: *Phase change material (PCM), Paraffin wax, Sodium sulphate decahydrate, Magnessium nitrate hexahydrate, Nickel nitrate Hexahydrate, Solar water thermal storage system.*

1. INTRODUCTION -

Due to time-dependent and unpredictable characteristics of sun exposure, utilization of solar thermal energy storage tanks with phase change materials can be done to enhance the performance of available solar water thermal systems. Phase change material absorbs heat during its phase change cycle from solid to liquid during the daytime solar cycle. The amount of heat that a tank of water can absorb is much higher with the presence of phase change material.

Phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. Phase Change Material or PCM have the capacity to store and release large amounts of energy that energy is called latent heat. Each PCM has specific melting and cristallisation temperature and a specific latent heat storage capacity. The analysis is carried out using one organic and three inorganic phase change materials including Paraffin wax, Sodium sulphate decahydrate, Magnessium nitrate hexahydrate and Nickel nitrate hexahydrate respectively.

1.1 Charging

The charging starts with circulation of the heat transfer fluid heated in the collection system at a temperature higher than the PCM melting temperature. This mode occurs during day time when solar energy collection takes place and terminates with complete melting of the PCM, charging of the store does not terminate with complete melting of the PCM if the inlet fluid temperature is above the melt temperature, charging of sensible heat continues.

1.2 Discharging

The discharging is started by circulation of the cold heat transfer fluid having inlet temperature lower than the PCM melting temperature. The heat transfer fluid exit temperature is time dependent because the rate of solidification of the PCM varies with time. This mode terminates with complete solidification of the PCM.

1.3 Procedure to carry out testing-

Fig - 1 Experimental set up

A Phase change material testing kit is used for analysis of materials and their charging and discharging are studied. For performing analysis first fill the water in both cold and hot water tank. Fill the required phase change material in glass assembly. Fix the heat exchanger to the unit. Then check the sensor position throughout points. Make sure the valves are properly adjusted for flow purpose.

Switch on the testing set up. Start heaters and heat the water up to required temperature. Start the pump and adjust required flow using flow meter. Pass the hot water and note down the readings as time in minute, hot water temperature, tube inlet temperature, tube outlet temperature, PCM temperature, ambient temperature using control panel. Measure the flow using flow meter provided to hot water as well as cold water unit.

Continue the process till the material going to change its phase from solid state to liquid. After it get converted to liquid stop the hot fluid flow and start cold fluid flow to convert it to its original phase.

1.4 PCM Used for Solar Water Heating System

Latent heat storage systems have many advantages like large heat storage capacity in a unit volume and their isothermal behavior during the charging and discharging processes.

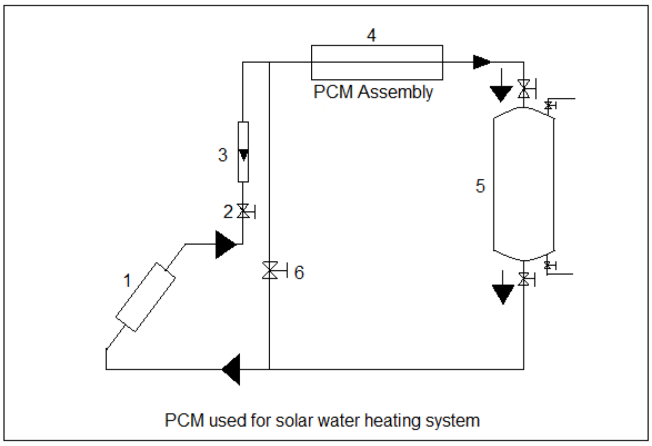

Fig – 2 PCM used for solar water heating

1- Solar flat plate collector
2&6- Flow control valves
3- Flow meter
4 - PCM assembly
5 - S tank

Figure shows a schematic diagram of the experimental setup. The PCM assembly is placed before storage tank. Solar flat plate collector of 2m2 surface area is coupled with the TES system. The capacity of the stainless steel tank is 50 lit and it is insulated with glass wool of 50mm thickness. For uniform flow of HTF, a flow distributor is provided on the top of the TES tank. The spherical capsules are stored from top to bottom keeping the wire mesh between each layer for providing the porosity. The total sensible and latent heat storage capacity of the TES is more getting using such materials. PCM can be useful during off sunshine hours.

2. RESULTS AND DISCUSSION -

The charging and discharging of four materials are ploted and studied. Among these four materials sodium sulphate decahydrate is suitable and having high heat of fusion. The charging characteristics of phase change material for all cycles of sodium sulphate decahydrate are plotted. The phase change material temperature increases steadily at given hot water flow. The phase change material sodium sulphate decahydrate starts melting at 0.8, 1, 1.2 LPM flow rates. Additives such as borax and gelatin gel are added at appropriate percentage to avoid congruent melting.

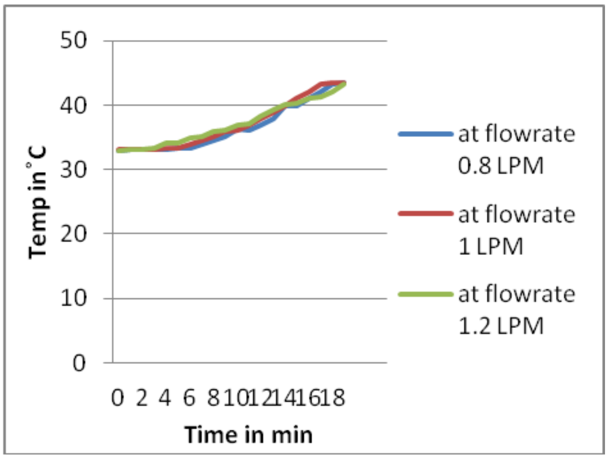

Chart – 1 Sodium sulphate decahydrate charging for all cycles

The discharging characteristics of phase change material for all cycles of sodium sulphate decahydrate are plotted. The phase change material temperature decreases steadily at given cold water flow. The phase change material sodium sulphate decahydrate starts solidifying at 0.8, 1, 1.2 LPM flow rates.

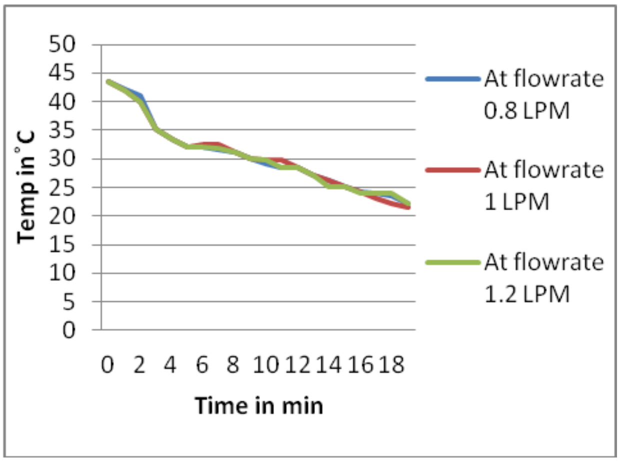

Chart - 2 Sodium sulphate decahydrate discharging for all cycles

In this way four materials are studied and collectively graph is shown for four materials Paraffin wax, Sodium sulphate decahydrate, Magnessium nitrate hexahydrate and Nickel nitrate hexahydrate as under.

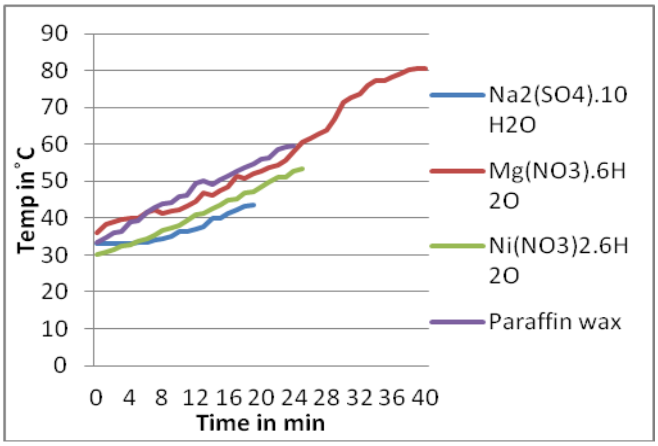

Chart – 3 charging graph of four materials

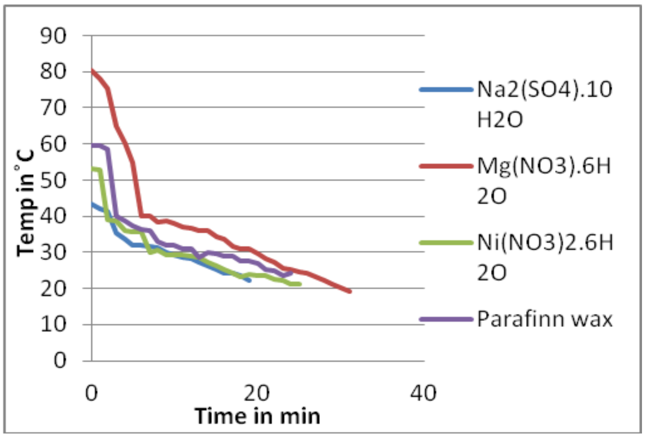

Chart – 4 discharging graph of four materials

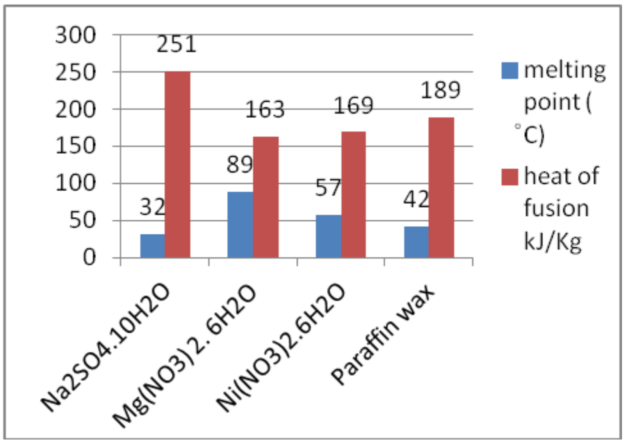

Chart – 5 Melting temperature and heat of fusion of four materials

The graph shows the melting temperature of sodium sulphate decahydrate, magnesium nitrate hexahydrate, nickel nitrate hexahydrate and paraffin wax is 32, 89, 57, and 42 respectively. The sodium sulphate decahydrate shows high heat of fusion among these materials in the range of 251 KJ/Kg.

3. CONCLUSION –

Inorganic PCMs have some attractive properties including: high latent heat values; higher thermal conductivity; not flammable; lower in cost in comparison to organic compounds; high water content means that they are inexpensive and readily available. As a result of the measurements, for sodium sulphate decahydrate stabilized with gelatin gel, incongruent melting and supercooling are prevented completely.

Among four material sodium sulphate decahydrate shows better performance with high heat storage capacity. Sodium sulphate decahydrate can be used for solar water thermal storage system as application of PCM which can be useful during off sunshine hours. Salt hydrates exhibit some problems when they are used as PCM. One of the problems is incongruent melting or phase segregation and the other problem is supercooling. It is covered by adding a nucleating agent.

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