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Experimental Study on Phase Change Material based Thermal Energy Storage System

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Abstract - *The use of phase change materials (PCM) is to store the heat in the form of latent heat and sensible heat, because large quantity of thermal energy is stored in smaller volumes. In Our experimental investigation, calcium chloride hexahydrate ($CaCl_2.6H_2O$) and sodium carbonate decahydrate ($Na_2CO_3.10H_2O$) used as a Phase change material and which is stored in copper tube and hot water is used as a heat transfer fluid (HTF) that flows across the copper tube to charge and discharge the phase change material storage system. The experimental design is prepared by considering the parameters: flow rate, heat transfer fluid inlet temperature, PCM temperature, Heat stored, PCM melting and solidification time (min). Experiments are conducted according to the experimental design and responses are recorded. The effect of selected parameters on TES using PCM is studied by analyzing experimental data. Analyzing of these two PCM we have calculated how much heat can be stored by PCM with respect to above parameters.*

Key Words: Phase change material [PCM] , salt hydrate, TES, HTF, Latent heat storage capacity.

I. 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.

PCM is capable of storing and releasing large amounts of heat energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. PCM have the capacity to store and release large amounts of energy, that energy is called as latent heat. Each PCM has specific melting, crystallization temperature and a specific heat storage capacity. The analysis is carried out using two inorganic phase change materials, such as calcium chloride hexhydrate ($CaCl_2.6H_2O$) and sodium carbonate decahydrate ($Na_2CO_3.10H_2O$).

A] Sensible heat storage system [SHS]:

Sensible heat storage system means the thermal energy is stored by raising the temperature of a solid or liquid. This system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging.

B] Latent heat storage system [LHS]:

A latent heat storage system based on heat absorption or heat release when a storage material undergoes a phase change from solid to liquid or liquid to gas. However some practical difficulties also arise applying the latent heat method due to low thermal conductivity, density change sub cooling of the phase change materials [3].The availability of solar energy is only during the day, hence application required to store this energy as much as heat is collected only the day time and this stored energy is used during the night time. There are different ways in which solar energy can be stored and one of the use is PCM. The PCM is an effective way to store the solar energy. The solar energy is free environmentally clean and therefore used as a most promising alternative energy resources option. The availability of total sunlight is seasonal and depend on the metrological conditions of the location (4).The present challenge is the storage of energy in suitable form which can be conventionally converted into required form. PCM is one of the most important methods for energy storage system.

C] PCM (Phase change materials):

A phase change material is a substance with a high heat of fusion, melting and solidifying at a certain temperature. It has a capable of storing and releasing large amount of energy. As compared to sensible heat storage material PCM have maximum heat storage capacity (almost 5-14 times more heat per unit volume). The selection of the PCM is totally based on a careful study of PCM properties of the substance. Each PCM is not an ideal PCM. The availability of PCM is also the factor to be considered. The total cost of PCM is depending on the purity of the material. At this particular time, a PCM become an important thermal energy storing component and is being under use in various thermal storage devices such as in automobile sector and for renewable energy applications. Due to their stability and maximum heat storing capacity these materials are most useful. In this paper two inorganic (salt hydrate) PCM's were studied such as $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$.

Table I: Thermophysical Properties of commercial Grade $CaCl_2.6H_2O$ and Na2CO3.10H_2O.

Physical Parameters	Phase Change Material	
	$CaCl_2.6H_2O$.	$Na_2CO_3.10H_2O$
Melting point(°C)	29-30	32
Specific heat (KJ/Kg°C)	Solid- 1.4 Liquid-2.1	Solid =1.88 Liquid=3.35
Latent heat of Fusion (KJ/Kg)	190	267
Density (g/cm^3)	Solid =1.68 Liquid=1.80	Solid=1.44 Liquid=1.46

II. METHODLOGY

Experiment set up:

Fig. 1 Experiment set up

Table II: Technical specifications of copper tube and stainless steel:-

Sr. No.	Tube	Material	Diameter mm	Length mm	Thickness mm
1	Inner	Copper	20	1080	1
2	Outer	Stainless steel	77	920	2

Procedure to carry out the testing-

1) Charging process :

In phase change material testing set up is used for analysis of materials for their charging and discharging process studied. For performance analysis first fill the water in both cold and hot water tank. Fill the required PCM in copper tube. Then check the sensor position throughout the points. Make sure the valves are properly adjusted for flow purpose.

Firstly switch on the testing set up. Start the heater and heat the water up to required temperature. Fill up the PCM into the copper tube as per the volume. Start the pump and adjust the flow rate for continues flow of water (Hot and Cold). Pass the hot water from stainless tube for melting the PCM which is present into the copper tube. PCM melts up to the melting point in the form of latent heat in which the temperature of storage material varies with the amount of energy stored. Alternatively thermal energy can be stored as a latent heat in which energy is stored when a substance change from one phase to another by melting process. Take out the readings as time in minute such as, 1) Hot water temperature 2)Tube inlet water temperature 3) PCM changing temperature 4) tube outlet water temperature, by using the thermocouples. Measure the flow rates using the flow meters provide to Hot as well as Cold water unit. Continue the process till the material going to change its phase from solid to liquid state. After getting highest temperature stop the hot water flow and take out the readings. Then start the cold water flow to convert liquid PCM to solid PCM by discharging process.

2) Discharging process:

The discharging process was started with the flow rate of 0.5 and 1lit/hr. The inlet temperature of cold water kept at the atmospheric temperature that is 32°C or lower than the PCM melting Temperature. During the discharging process the cold water is circulated through over the copper tube.Now the heat energy stored in PCM is transferred to the cold water so the cold water temperature is increased .temperature of the PCM and HTF are recorded at intervals of 5 min. The discharging process is continued until the PCM temperature reduces to atmospheric temperature. The temperature of HTF at inlet and outlet are recorded .Also the temperature of the PCM at two location are recorded. Like that the flow rate changed to 1 lit/min and the PCM and HTF temperature are recorded. The heat transfer fluid exit temperature is time dependent because the rate of solidification of the PCM varies with the time. This mode terminates with the solidification of the PCM

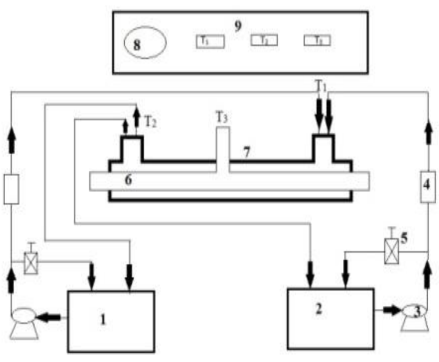

Fig.2: Line diagram of Experimental setup.

1. Hot water tank. 2. Cold water tank. 3. Pump. 4. Flow meter. 5. Gate valve. 6. Copper tube. 7. Stainless steel tube. 8. Power supply. 9. Temperature indicators.

III. Results and discussion

1) Charging process (Heat stored)

The charging starts with circulation of heat transfer fluid heated in the collection system at a temperature higher than the PCM melting temperature. This Mode occurs during the supply of hot water and heat energy stored up to the complete melting of the PCM.

A] Charging effect on different flow rate for $CaCl_2.6H_2O$ as a PCM

Fig.3 illustrates the effect of varying the mass flow rate of HTF (0.5 and 1lit/min) during the charging process. Increase in mass flow rate has a small effect on the phase transition process of PCM. As the flow rate is increased (0.5 to1 Lit/min) the heat storing as well as heat releasing capacity increased.

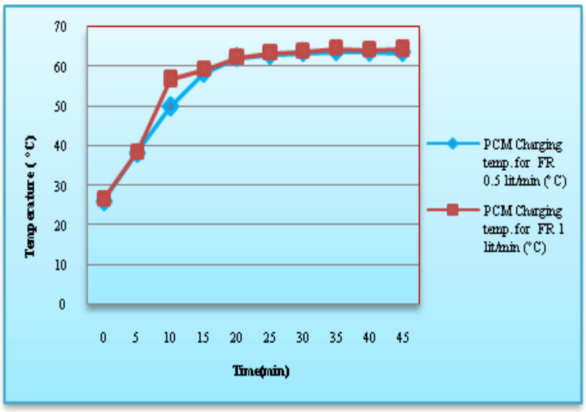

Fig 3: Charging effect for Time Vs Temperature

B] Charging effect on different flow rate for $Na_2CO_3.10H_2O$ as a PCM

Fig 4 illustrate the effect of varying the mass flow rate of HTF (0.5 and 1lit/min) during the charging process. Increase in mass flow rate has a small effect on the phase transition process of PCM. As the flow rate is increased (0.5 to1 lit/min) the heat storing as well as heat releasing capacity increased.

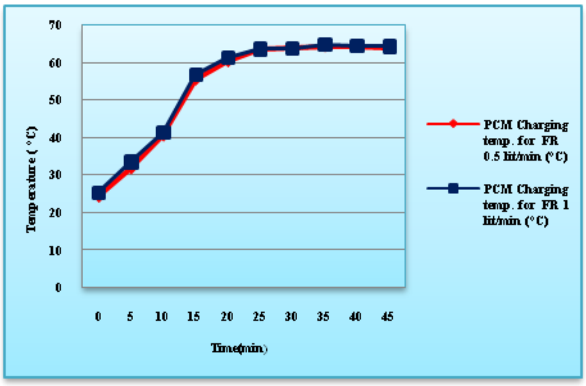

Fig.4: charging effect for Time Vs Temperature

[2] Discharging process

Discharging temperature of $CaCl_2.6H_2O$

The discharging process is started by circulation of cool water over the liquid PCM. The heat transfer fluid exit temperature is time dependent because the rate of solidification of the PCM varies with the time. This mode terminates with solidification of the PCM.

A] Discharging effect of PCM on flow rate 0.5 lit/min for $CaCl_2.6H_2O$

Fig 5 shows the outlet variation for $CaCl_2.6H_2O$ and cold water. The graph shows the cold water absorbs the heat from the PCM Temperature and increased cold water heat heat upto the 34°C.

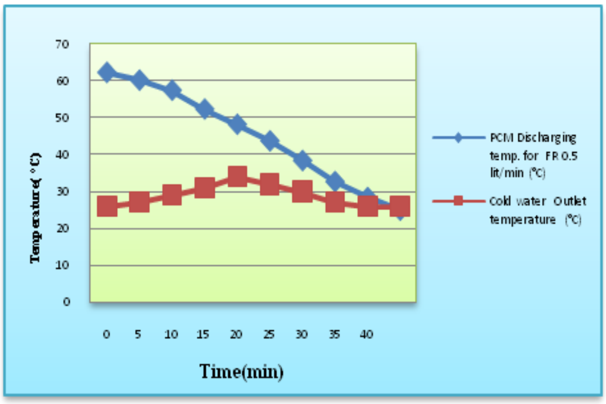

Fig 5: Discharging effect for Time Vs Temperature

B] Discharging effect of PCM on flow rate 1lit/min for $CaCl_2.6H_2O$

Fig 6 shows the outlet variation for $CaCl_2.6H_2O$ and cold water. The graph shows the cold water absorbs the heat from the PCM Temperature and increased cold water heat up to the 34°C.

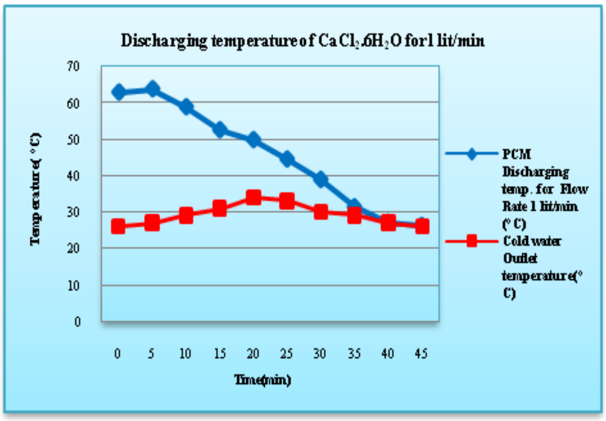

Fig 6: Discharging effect for Time Vs Temperature

C] Discharging effect of PCM on flow rate 0.5lit/min for $Na_2CO_3.10H_2O$

Fig 7 shows the outlet variation for $Na_2CO_3.10H_2O$ and cold water. The graph shows the cold water absorbs the heat from the PCM Temperature and increased cold water heat up to the 35°C.

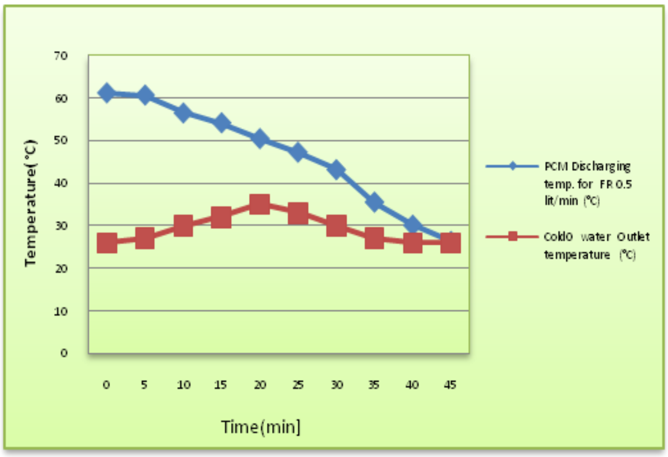

Fig 7: Discharging effect for Time Vs Temperature

D] Discharging effect of PCM on flow rate 1lit/min for $Na_2CO_3.10H_2O$

Fig 8 shows the outlet variation for $Na_2CO_3.10H_2O$ and cold water. The graph shows the cold water absorbs the heat from the PCM Temperature and increased cold water heat up to the 36 °C.

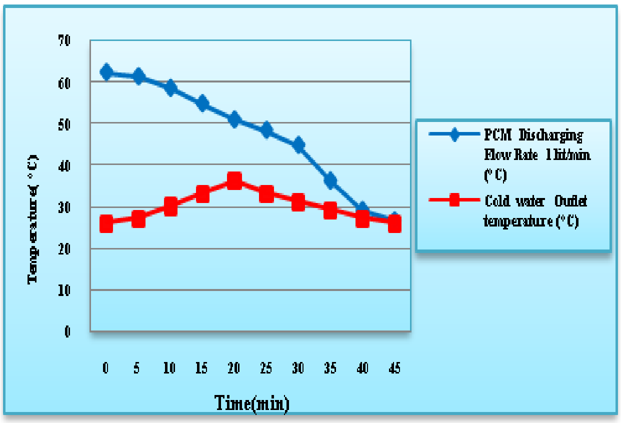

Fig 8: Discharging effect for Time Vs Temperature

[3] Comparison discharging temperature Graph between $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$ For flow Rate 0.5 lit/min

Fig.9 graphically compares the heat stored between the $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$ when the flow rate is 0.5 Lit/min. It is observed that the heat stored in $Na_2CO_3.10H_2O$ is higher than $CaCl_2.6H_2O$.when flow rate is increased the heat storing as well as heat realizing capacity increased.

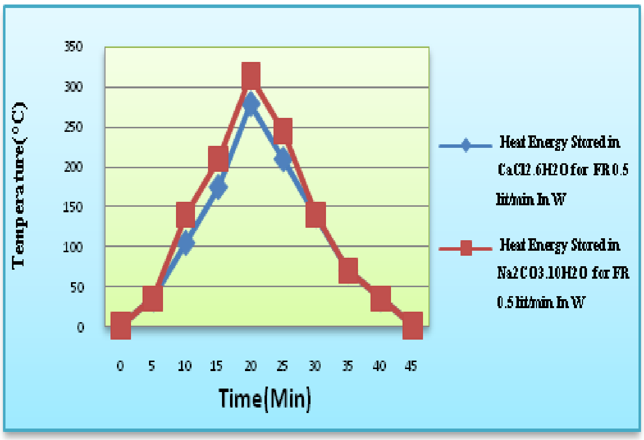

Fig.9: Comparison discharging temperature Graph between $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$ For flow Rate 0.5 lit/min

[4] Comparison discharging temperature Graph between $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$ For flow Rate 1lit/min

Fig.10 graphically compares the heat stored between the $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$ when the flow rate is 1 lit/min. It is observed that the heat stored in $Na_2CO_3.10H_2O$ is higher than $CaCl_2.6H_2O$.when flow rate is increased the heat storing as well as heat realizing capacity increased.

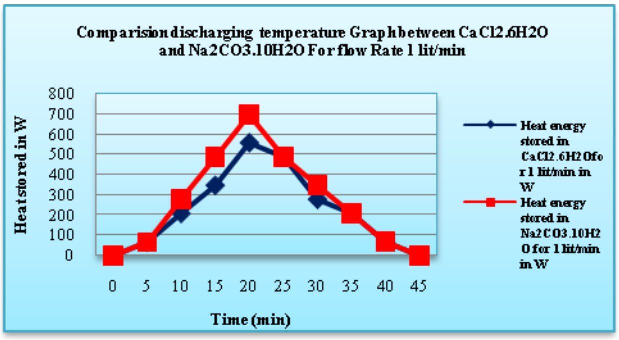

Fig10: Comparison discharging temperature Graph between $CaCl_2.6H_2O$ and $Na_2CO_3.10H_2O$ For flow Rate 1lit/min

[5] Thermal performance of the PCM System for $CaCl_2.6H_2O$

Table 4 shows the performance of the $CaCl_2.6H_2O$ with two different flow rates. In this table energy released by the hot water during charging mode (W) is 2267.1W at 0.5lit/min and 4535.1w at 1lit/min. The Energy gained by the cold water during discharging mode (W) is 1045.6 W at 0.5lit/min and 2232w at 1lit/min. The efficiency at 1lit/min is 49.2% and the efficiency at 0.5 lit/min is 46.1% .In this realized that when the flow rate is high the heat storing capacity and efficiency is high.

Table 4: Thermal performance of the PCM System for $CaCl_2.6H_2O$

Experiment no.	I	II
Flow rate during Charging mode	0.5 lit/min	1 lit/min
Flow rate during discharging mode	0.5 lit/min	1 lit/min
Energy released by the hot water during charging mode (W)	2267.1W	4535.1 W
Time interval during charging mode (min)	5 Min	5 Min
Energy gained by the cold water during discharging mode (W)	1045.6 W	2232 W
Time interval during discharging mode (min)	5 Min	5 Min
Efficiency	46.1 %	49.2%

5] Thermal performance of the PCM System for $Na_2CO_3.10H_2O$

Table 5 shows the performance of the $Na_2CO_3.10H_2O$ with two different flow rates. In this table energy released by the hot water during charging mode (W) is 2267.1W at 0.5lit/min and 4535.1w at1lit/min. The Energy gained by the cold water during discharging mode (W) is 1185.2 W at 0.5lit/min and 2927.9 W at 1 lit/min. The efficiency at 1 lit/min is 64.5% and the efficiency at 0.5 lit/min is 52%.In this realized that when the flow rate is high the heat storing capacity and efficiency is high.

Table 5: Thermal performance of the PCM System for $Na_2CO_3.10H_2O$

Experiment no.	I	II
Flow rate during Charging mode	0.5 lit/min	1 lit/min
Flow rate during discharging mode	0.5 lit/min	1 lit/min
Energy released by the hot water during charging mode (W)	2267.1W	4535.1 W
Time interval during charging mode (min)	5 Min	5 Min
Energy gained by the cold water during discharging mode (W)	1185.2 W	2927.9W
Time interval during discharging mode (min)	20 Min	25 Min
Efficiency	52%	64.5%

IV. CONCLUSIONS

1) It is observed that the heat stored in 1lit/min is higher than 0.5lit/min .so when flow rate is increased the heat storing as well as heat releasing capacity increased.

2) When flow rate is higher the efficiency of the set up increasing.

3) As per the performance in the Charging (heat storing) and discharging processes, there is much difference between PCM's. But $Na_2CO_3.10H_2O$ performance is slightly better (5-7%) than $CaCl_2.6H_2O$ because of latent heat and specific heat variation.

4) It means that Both PCMs are suitable for thermal energy storage system but $Na_2CO_3.10H_2O$ is better than $CaCl_2.6H_2O$

REFERENCES

1) Thirugnanam.C, Marimuthu.P , " Experimental Analysis of Latent Heat Thermal Energy Storage using Paraffin Wax as Phase Change Material "International Journal of Engineering and Innovative Technology (IJEIT) (2013) 372-376 .

2) R. Meenakshi Reddy, N. Nallusamy, and K. Hemachandra Reddy Experimental Studies on Phase Change Material-Based Thermal Energy Storage System for Solar Water Heating Applications Ashdin Publishing Journal of Fundamentals of Renewable Energy and Applications Vol. 2 (2012),

3) Kondakkagari Dharma Reddy, Pathi Venkataramaiah, Tupakula Reddy Lokesh Parametric Study on Phase Change Material Based Thermal Energy Storage System" Energy and Power Engineering, (2014) , 537-549

4) Ganesh Patil1, Prof. (Dr.) C. H. Bhosale, Prof. N.N.Shinde , Prof.M.M.Wagh Analysis of Various Phase Change Materials and its Application for Solar Water Thermal Storage System (IRJET) 1352 -1355

5)B.Meganathan,G.R.Vignesh,R.Giritharan2,N.R.Vigneshwaran2, K.Sasikumar, "Alternate Heat Energy Storage Using PCM" Vol. 6, Issue 3, March 2017(IJIRSET) 4482-4487

6) R. Senthilkumar, N.Sithivinayagam N. Shankar "Experimental Investigation of Solar Water Heater Using Phase Change Material" International Journal of Research in Advent Technology, Vol.2, No.7, July 2014 79-88

7)M. A. Boda, R. V. Phand, A. C. Kotali "Various Applications of Phase Change Materials: Thermal Energy Storing Materials" International Journal of Emerging Research in Management &Technology(Volume-6, Issue-4) 167-171

8) M.J. Kabbaraa , N.Ben Abdallaha .Experimental investigation on phase change material based thermal energy storage unit. Published by Elsevier Ltd. (2013) 694 – 701

9) Hasan A. Phase change material energy storage system employing palmitic acid. Solar Energy 1994; 52:143–54.

10) Ettouney, H., El-Dessouky, H. & Amani Al-Ali. (2005). Heat transfer during phase change of paraffin wax stored in spherical shells. ASME Journal of Solar Energy Engg., 127, 357-365

11) Buddhi, D., Bansal, K., Sawhney, R.L. & Sodha, M.S. (1988). Solar thermal storage systems using phase change materials. Int. J. Energy Research, 12, 547-555.

12) Sharma, A., Tyagi, V.V., Chen, C.R. and Buddhi, D. (2007) Review on Thermal Energy Storage with Phase Change Materials and Applications. Rnewable and Sustainable Energy Reviews, 13, 318-345