ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10, No.1, pp 560-564, 2017

Experimental Investigation on Latent Heat Storage for Space Heating using Concentrated Solar Collectors

C. Arun Sekharan[1], P. Sundaram[2]*, R. Senthil[3]

[1]Executive Engineer, Innovative Petrochemical Engineering Service Pvt. Ltd., Navi Mumbai-400 706, India.
[2,3] Department of Mechanical Engineering, SRM University, Kattankulathur-603 203, India.

Abstract : Most of the solar thermal applications operate innon-concentrated and concentratedmodes. Thermal energy storage (TES)in solar applications is beneficial to meet the thermal needs. Phase change materials (PCM) are preferred for TES. The selected PCM are Magnesium Chloride hexahydrate and Erythritol. TES is investigated experimentally with air as heat transfer fluid (HTF)and results showed the use ofErythritol gives better performance than $MgCl_2.6H_2O$ due to its higher latent heat.
Keywords : Air dryer, thermal storage, solar collector, phase change materials.

Introduction

The solar radiation is available at the Earth's surface, but intensity level varies from zero to around 1 kW/m^2. A solar PV and thermal system with around 10% conversion efficiency can easily fulfill the India's energy needs. The cost of energy production from solar is still 3-4 times higher than the fossil fuel power. The solar energy utilization improves the health our planet from the usage of fossil fuels and the subsequent global warming due to its harmful emissions. TES is the main integral part of solar thermal applications due to intermittent and fluctuating nature of solar energy. Chee et al.[1] tested the double reflector concept. Sebai et al.[2] investigated on the hydrate of Magnesium chloride. Effect of PCM in the storage and solar thermal system was examined by several researchers[3-6]. Murali and Mayilsamy[7] discussed the usage of PCM for water heating. Senthur Prabhu and Asokan[8] demonstrated 7% saving of fuel through PCM based thermal storage for engine exhaust. Potential uses of PCM were discussed by Janarthanan and Suresh Sadagopan[9].This work involves the experimental work on PCM storage with air as working medium. Two PCMs are investigated, and results are reported.

Materials and Methods

The aperture of main dish is 1.13 m^2(0.19 m deep) and used to reflect the incident sunlight to the secondary dish of 0.071 m^2 area (0.076 m deep). The TES system was charged by the concentratedsun rays from the small reflector. Tests were performed for its charging and heat retrieval process for the air heating. The HTF inlet and outlet temperatures are measured for the continuous as well as intermittent operations to evaluate the performance of TES. Figure 1 shows the schematic layout of experimental setup.

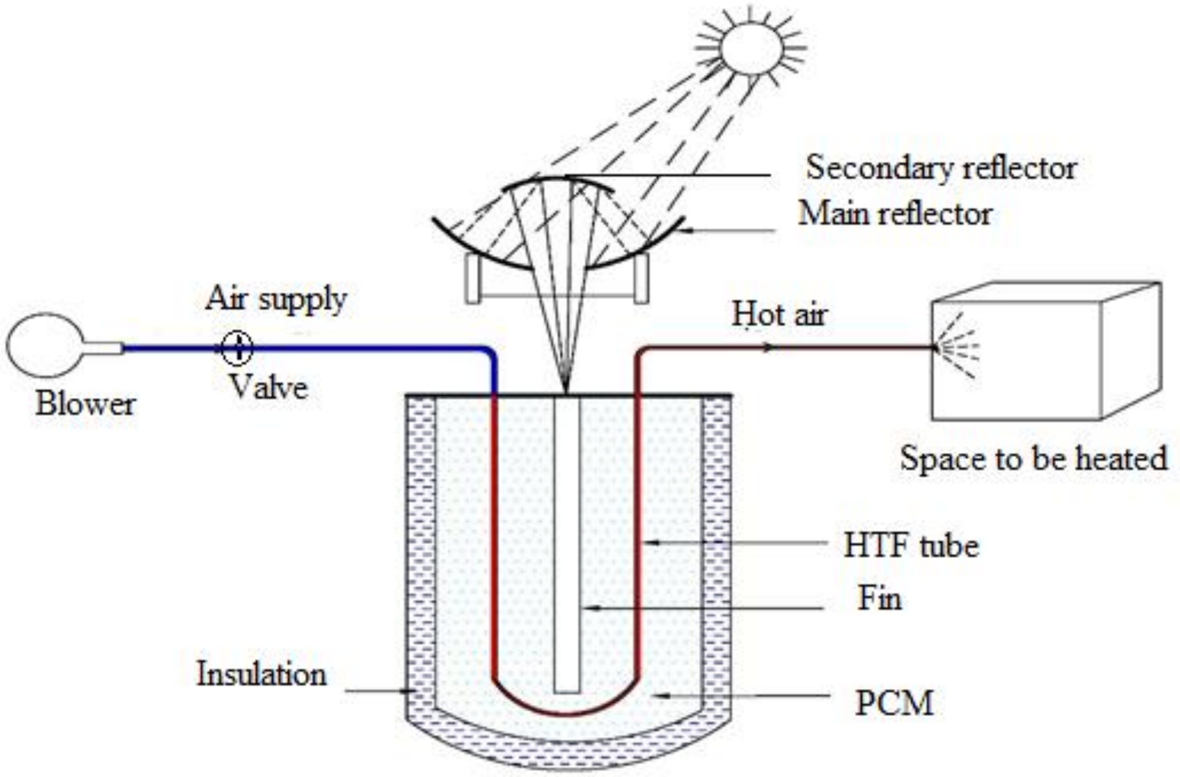

Figure 1. Schematic layout of experimental setup

Table 1. Properties of selective PCMs

PCM	$MgCl_2.6H_2O$	$C_4H_{10}O_4$
Melting point, T_m	116.7 °C	118 °C
Melting enthalpy	168.6 kJ/kg	339.8 kJ/kg

PCMs were tested experimentally for charging and discharging process and compared successfully. The mass of PCM tested is 4.25 kg. The properties of PCMsare given in Table 1.The size of the cylindrical tank storage is 300 mm long and 110 mm diameter. The experimental trail is conducted throughout the day at bright sunshine hours for both Magnesium Chloride hexahydrate and Erythritol storage tank set-up. The concentrated sunlight absorbed by the receiver plate as heat and transferred to the fin. The heat energy transfer from fin toPCM material due to convection and conduction heat transfer depend on the intensity of solar radiation.

Result and Discussion

The average solar radiation intensity was 596.3 (range 288-783 W/m^2) and 608 W/m^2 (range 281-778 W/m^2) on 5th and 10th April 2016 respectively. The wind velocity was around 0,2-2.1 m/s on both days. However, the storage was not having significant heat loss due to wind. The results for the air flow rate of 1 m^3/min for the both PCMs are compared. The experimental results showed the hot air supply of 40 - 60°C. The results are shown in fig. 2 - 6.The HTF heat gain (Q_u) givenin equation (1),

$$Q_u = \dot{m} C_p (T_o - T_i) \qquad (1)$$

Where, C_p- liquid specific heat, $\dot{m}$ - mass flow rate, T_i and T_o- entry and exit temperature of HTF.

Theheat energy stored in the PCM in which its specific heat (C_p), temperature range (dT) and latent heat (H) is expressed as:

$$Q_{st} = m_{pcm}\left[\int_{T_i}^{T_m} C_{ps}\,dT + H + \int_{T_m}^{T_f} C_{pl}\,dT\right] \quad (2)$$

The direct charging of thermal mass material undergoes sensible heating as well as phase change process inside the TES container.

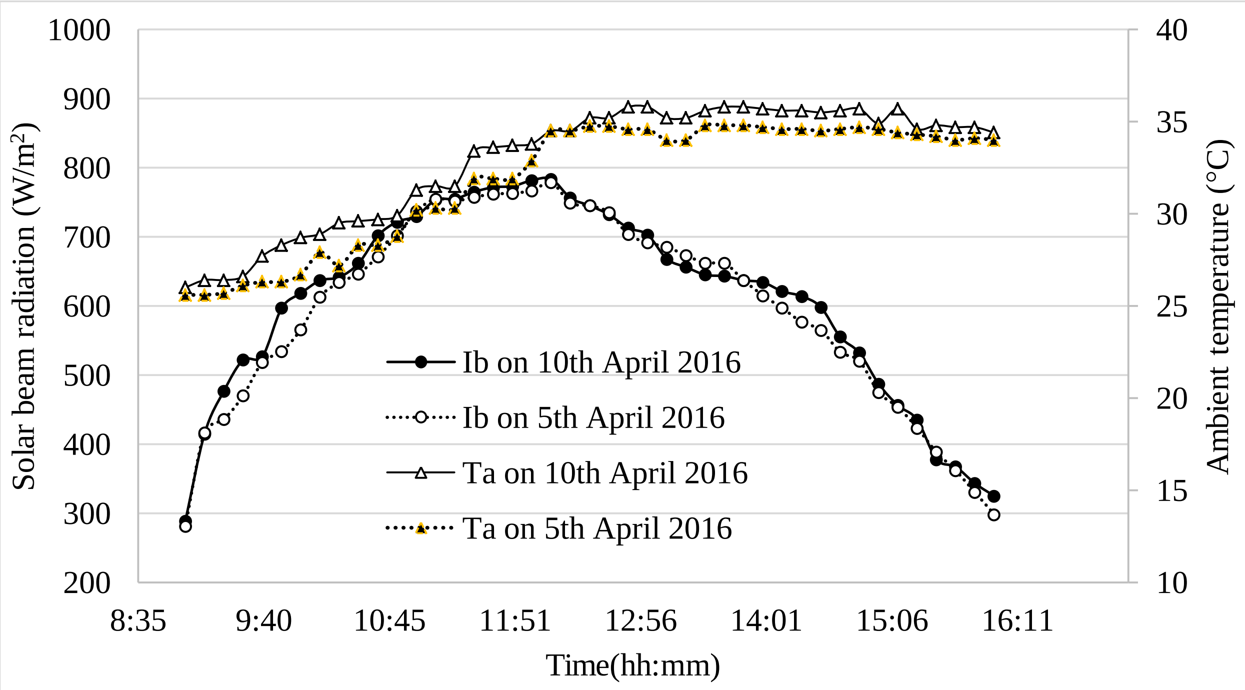

Figure 2. Solar beam intensity and ambient temperature (5th April 2016)

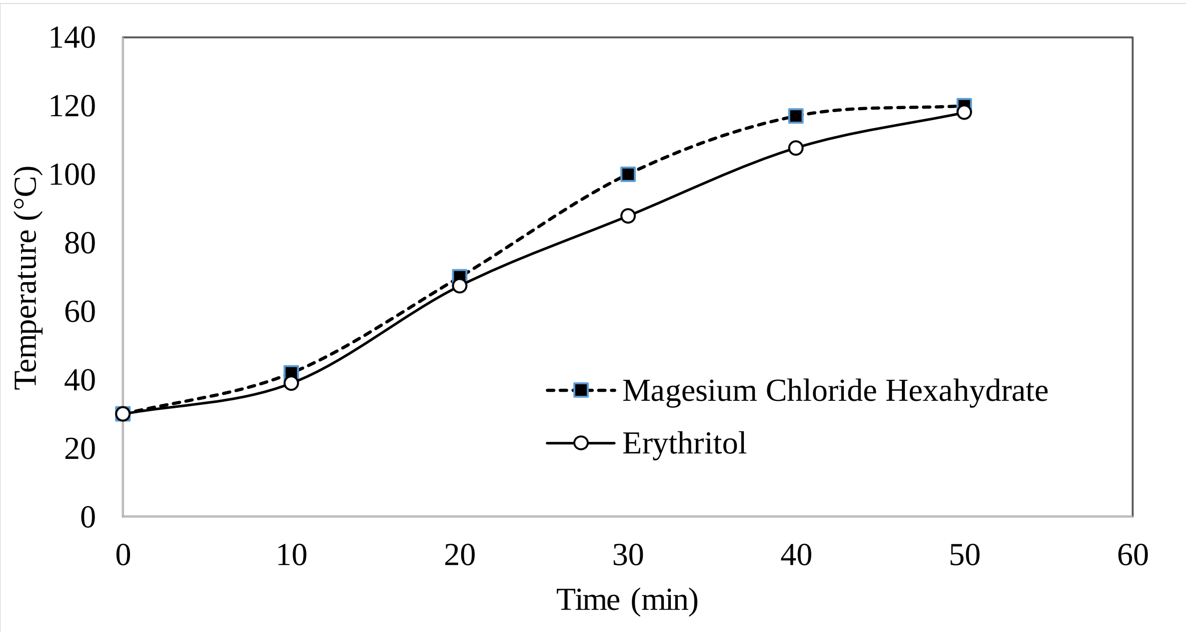

Figure 3. Charging of PCM

The ambient temperature varied around 25.6 – 34.8°C and 26 - 35.8°C on 5th and 10th April 2016 respectively. The radiation and ambient temperature on both test days were observed with a little variation of 2% and 3% respectively. The testing of both PCMs are tested outdoor on alternative days. other test days are ignored. The similar radiation conditions are considered in the analysis. Figure 3 shows that the temperatures of

PCM while charging and discharging of PCM from TES tank. it can observe the change of state of PCM with respect to intensity of solar radiation. The complete melting of PCM in the storage was done in an hour of testing.

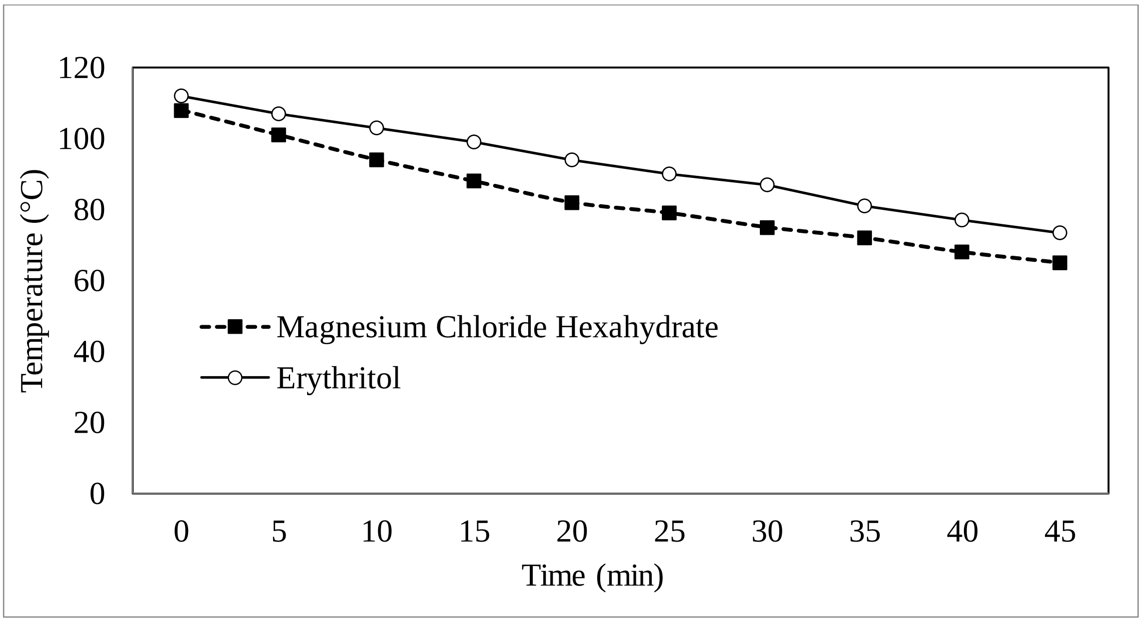

Figure 4. Discharging of PCM for a air flow rate of 1 m^3/min

The discharge experimentsstarted after charging of PCM. The drop in outlet temperature was observed during the discharging of PCM.The energy stored in the PCM was retrived by passing air through the storage at 1 m^3/min (Fig. 4). The storage is capable of supplying heat output of air around 80-90 °C for 30-45 minutes. The lower flow rate of air supply through the storage produced hot air around 60 – 80°C for an hour. Erythritol showed slightly better performance due to its higher latent heat.

Conclusion

Magnesium chloride hexahydrate and erythritol wereinvestigated experimentally. Both are good enough to supply the hot air for drying or space heating application in the range of 60-80°C. The combined sensible and latent heating takes place inside the storage container, and the latent heating dominates at this selected solar collection system around a peak of 780 W/m^2. Erythritol showed slightly better performance than $MgCl_2.6H_2O$ due to its higher latent heat. The combination of PCMs can serveenhanced energy storage.

References

1. Chee Woh Foong, Ole Jorgen Nydal, Jorgen Løvseth.” Investigation of a small scale double-reflector solar concentrating system with high-temperature heat storage”, Applied Thermal Engineering, 31 (2011) 1807- 1815.
2. A.A. El-Sebaii, S. Al-Heniti, F. Al-Agel, A.A. Al-Ghamdi, F. Al-Marzouki, “One thousand thermal cycles of magnesium chloride hexahydrate as a promising PCM for indoor solar cooking”, Energy Conversion and Management, 52 (2011) 1771–1777.
3. Senthil, R., Cheralathan, M., Effect ofPCM in a solar receiver on thermal performance of parabolic dish collector, Thermal Science (2016) doi: 10.2298/TSCI150730007S
4. Ramalingam Senthil, Marimuthu Cheralathan, Effect of Once-through and Recirculated Fluid Flow on Thermal Performance of Parabolic Dish Solar Receiver, Indian Journal of Science and Technology, 9 (2016), 33, pp. 1-5
5. P. Sundaram, Rahul Kumar Tiwari, Sanat Kumar, Experimental Performance Study of Helical Coil Thermal Storage Unit Filled with PCM, International Journal of ChemTech Research, Vol.9, No.07 pp 611-618, 2016.

6. Ramalingam Senthil, Marimuthu Cheralathan, "Natural heat transfer enhancement methods in phase change material based thermal energy storage". International Journal of ChemTech Research, Vol. 9, No. 5, 2016, 563-570.
7. Murali G., Mayilsamy K., "An overview of PCM usage to enhance solar water heating system", International Journal of ChemTech Research, 2015, 7(4), pp 1802-1807.
8. SenthurPrabhu S, Asokan M.A., "A study of waste heat recovery from diesel engine exhaust using phase change material", International Journal of ChemTech Research, 2015, 8(6), pp 711-717.
9. Janarthanan B, Suresh Sagadevan, "Thermal Energy Storage using Phase Change Materials and their Applications: A Review", International Journal of ChemTech Research, 2015, 8(6), pp 250-256.

*****