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Experimental Investigation of Performance on A PCM Assisted Solar Water Heater

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Abstract- **Latent heat thermal energy storage is one of the most efficient ways to store thermal energy for heating water by receiving energy from sun. This paper summarizes the investigation and analysis of thermal energy storage incorporating with and without Phase Change Materials (PCM) for use in solar water heaters .This energy is utilized to heat water for domestic purposes during night time. This ensures the hot water availability throughout the day. The system consists of two simultaneously functioning heat-absorbing units. One of them is a solar flat plate collector and the other a heat storage unit consisting of PCM (paraffin). The water heater functions normally and supplies hot water during the day. The storage unit stores the heat in PCMs during the day which supplies hot water during the night. The storage unit utilizes cylindrical tubes made of copper and curved cylindrical tubes made of steel filled with paraffin wax as the heat storage medium. The performance of both the geometries are analyzed and compared in this work. The water in the storage unit receives heat form the heating panel and transfers it to the PCM. The PCM undergoes a phase change by absorbing latent heat, excess heat being stored as sensible heat. During night hours the stored energy is transferred to cold water again by the phase changing process till the liquid phase of paraffin become solid phase. The present experiment focuses to maintain 60 liters of water at a temperature of around 70oC during the day time with a flow rate of 5 ml/sec through a flat plate collector. Copper is used for the collector plate and the runner tube and the storage tank is of stainless steel material. The melting point of Paraffin is 56oC. By the application of PCM the hot water availability can be extended up to 4 hours than the normal condition.**

Keywords:- Solar water heater , Latent heat thermal energy storage, Phase Change Materials, phase changing process.

I. INTRODUCTION

The primary energy sources in the earth are eliminating day by day due to the higher consumption rates .The increasing population and the human comfort level standards speedup the crises level and it leads to the effective utilization of secondary energy sources. The large scale application of fossil fuels causes atmospheric pollution by the evolution of harmful gasses in large scale like nitrogen oxides (NOx), sulphur oxides(SO2),carbon monoxide and carbon dioxide(CO &CO2), hydrocarbons, suspended particles and fly ash. Due to these pollutants causes ozone layer depletion, health hazards, global climate change and global warming etc. The secondary sources are mainly of solar, wind, tidal, wave, hydro and geothermal energies. In which the main energy source is of the sun and these alternative sources are the manifestation of solar energy. The solar energy is freely available and is environmentally clean. So this energy is accepted as the most promising alternative energy. The effective utilization of solar energy is not at all popular and common in this modern scenario. The domestic hot water application consumes above 45% of energy produced worldwide. By the effective utilization of solar energy can control the energy crises and atmospheric pollution all over the world. The solar energy obtained only in day timings and the major requirement of hot water arises in the night hours and the morning. The major difficulties are the intermittent and variable supply due to the clouds and the large area requirement of the collector. The energy supplied by the sun keeps the temperature level of the Earth for the human beings, animals and all the species and the temperature level of ocean and land to cause the air circulations and the photosynthesis in plants.

The solar energy incident over the atmosphere is 1017watts in which the incidence on the earth surface is 1016 watts. The total power demand all over the world is 1013watts.The solar radiation in a normal sunny day is around 1Kw/m2 [1].From this figures it is clear that the energy available is 1000 times more than that we required. If we can utilize 1% of this energy, it will be 10 times the total world will require. The diameter of sun is 1.39 x106 and the earth is of 1.27 x 104.The mean distance between the two is 1.50 x 108 km[1].The sun is a hydrodynamic spherical body of extremely hot ionized gases called plasma. The energy is produced by the process of thermonuclear fusion. The temperature inside the sun is estimated as 8 x106 K to 40 x 106 K.The energy is emitted by the fusion of hydrogen to helium [2].The radiated energy is in the form of electromagnetic waves in which 99 percent have wavelengths from .2 to 4. Micrometers. The solar energy reaching the top of the earth's atmosphere consists of about 6.4 to 8 per cent ultraviolet radiations (λ<0.38µm), 46 to 48 per cent visible light (0.38 µm<λ <0.78µm) and 46 per cent infrared radiation (λ >0.78µm) of total energy [1, 2].The successful applications of solar energy are of solar water heating for domestic purposes, electric power generation, solar cookers, solar driers, heating and cooling of residential buildings, solar distillation, food refrigeration etc.

A domestic solar water heater with latent heat thermal energy storage by phase change material is experimentally conducted and analyzed in this paper. The solar radiations incidents over a black collared copper flat plate collector is absorbed and converted to heat energy. Two thermocouples one at the right side bottom and another at the left side top is fitted for proper measurements below the flat plate collector.

The top surface is covered by transparent glass plate to create greenhouse effect and on the same time the thermal insulation. The bottom and side portions are covered with thermoocole.The whole assembly is packed in a wooden frame with necessary plumbing arrangements. The working fluid (water) circulates through the copper runner tubes which transfers the heat and is then collected in the storage tank. The storage tank is made of stainless steel fitted with thermocouples at 1/4th and 3/4th of the total height. The hot water outlet pipe is also fitted 3/4th of the height on the opposite side. The hot water supply to the storage tank is fitted at the bottom portion. The hot water obtained by solar collectors not at all retains the temperature up to morning section. The PCM can maintain the temperature in the storage tank by the phase change process. The efficiency variations for different geometries of energy storage mediums are analyzed and compared with out the usage of PCM.

II. METHEDOLOGY

The experimental setup consisting of a solar flat plate collector, an insulated box for the collector, an insulated storage water tank, cylindrical copper tubes and curved cylindrical steel tubes filled with phase change material (paraffin), and a thermal indicator.

Description	Specification
Collector dimensions	1.7m x 0.9 m x 0.1 m
Number of glass covers	1
Glass cover transmissivity	0.88
Cover thickness	4 mm
Absorber plate dimensions	1.50 m x 0.80 m
Absorber plate, Header and Riser material	Copper
Thermal conductivity of the plate material	386 W/m °C
Plate thickness	1mm
Absorber area	1.2 m^2
Absorptivity	.65
Header tube size	Φ19.5 mm
Riser tuber size	Φ9.5 mm
Number of riser tubes used	10
Insulation material &Thermal conductivity	Polyurethane form,0.64W/mK Expanded polystyrene,0.034W/m k
Insulation thickness	5cm
The average solar insolation	709W/m^2
Location of collector	Kasaragod, 12.5 N, 75.00 E

The flat plate collector is the absorbing unit of the solar radiations which consists of a copper plate of 1mm thickness. The flat plate collector serves as the solar energy converter to heat energy having an area of 1.2m2. Copper tubes are brazed over the plate with bottom and top header pipes for the circulation of the heat transfer fluid. The plate surface is coated with a black enamel paint to control the reflection of the emitted radiation to the atmosphere. Two K type thermo couples are fitted on the back side of the copper plate to measure the temperature instantly. The first one is fitted on the right side bottom portion and the other is on the left side top portion. The temperature of plate at the bottom and top is varied due to the water circulation. The thermocouple voltage can be measured with help of an indicator.

The flat plate collector is positioned in an insulated wooden box .The sides and bottom are well insulated with thermocol. The top surface is covered with a glass plate of 3mm thickness.The sides and bottom insulation helps to reduce the conduction and convection lossess.The top cover helps to reduce the convective as well as the radiativelossess.The glass plate have the property to transmit short waves and to reflect the long wave radiations.

Thus by introducing a glass cover we can create a greenhouse effect such as the short wave solar radiations are transmitted to the plate collector and the reflected long wave radiations are trapped in the box section. The height from the plate to the glass cover is arranged as 4cm.for better heating conditions. Instead of the thermocol insulations the wood is also a god insulation material. Poly urethane form is also introduced on the top edges to avoid the heat loss and to create an air tight condition.

The water storage tank is made of galvanized iron sheet with a volume of 72m3.The tank is provided with two thermocouples.The first one is fitted on the center of the tank through the side wise position and the other one is fitted 3/4th of the total height from the bottom. The water inlet to the collector is poured through piping from the bottom of the storage tank. The hot water is returned to the storage tank through piping to the 3/4th of the total height from the bottom.

The storage tank is possioned 110m height from the ground for getting proper head. The top of the storage tank is opened to facilitate the possioning of the PCM geometries. The tank is properly insulated with poly urethane form to avoid the heat loss to the surroundings.

The cylindrical copper tubes are used for the encapsulation of the paraffin wax. The length of the tube is 45cm and the inner diameter is 14mm and the thickness is 0.9mm.The paraffin wax is melted and filled in to the tube and the ends are properly sealed. The copper tube contains 55grams of wax and the total weight is 770 grams for 14 tubes. The PCM tubes are arranged in such a way that the top half of the water is in contact with the tubes.

The cylindrical curved steel tubes filled with PCM is also used for the comparison purposes. The steel tube having inner diameter 15.5mm and the thickness of wall is 1.25mmThe steel tubes contain 77grams of wax and the total weight is 770 grams for 10 tubes.

The thermal indicator is a voltage measuring instrument in which the emf produced from the thermocouple due to temperature variations is measured. The ambient temperature can also be measured with these instruments.

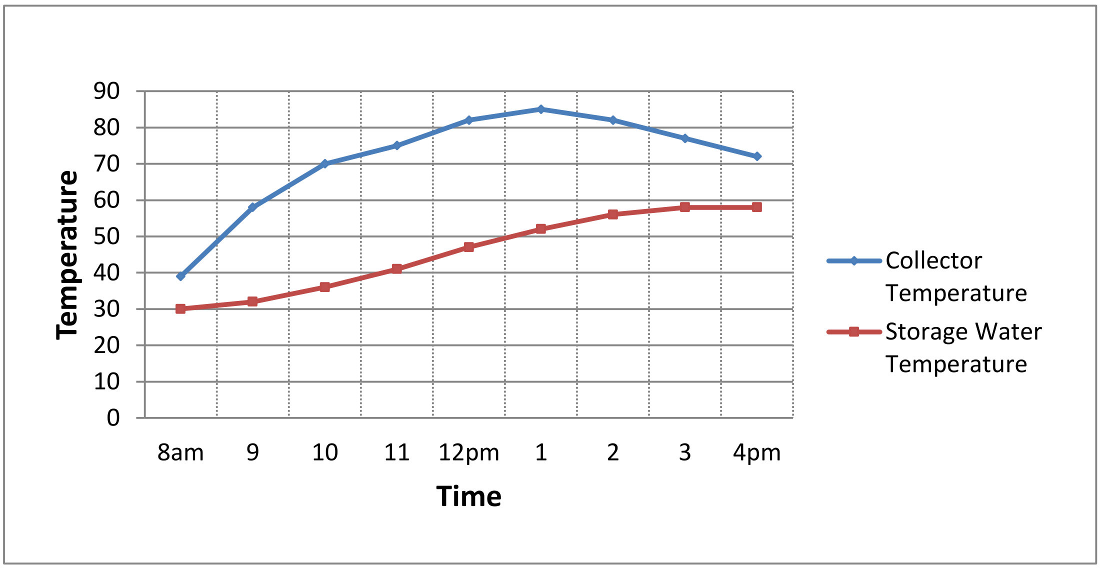
The phase change material used in this experimental study is n-Hexacosane ($C_{26}H_{54}$). It is a Paraffin wax which contains 26 carbon atoms and having a melting point of 56.4o C. The latent heat of fushion-256 J/g, Dencity-0.778 g/ml, Boiling point- 412.2°C, Molar mass - 366.71 g/mol

III. EXPERIMENTAL PROCEDURE

The experimental work is conducted at Kasaragod District (Kerala State, India) The latitude 12.5N, longitude 75.00 E. The experiments are conducted from 2015 April 22 to April 30.Solar energy available in the location is 6.39 Kwh/m2-day.The wind speed in the location is taken as 2m/s. The experimental setup is fabricated by locally available materials with cheap rates such as wooden battens, thermo Cole sheets, poly urethane forms etc. The experimental setup is mainly aiming to perform as passive system by thermo syphon effect. The effects in mass flow rates are also studied. The PCM is encapsulated in two geometries and the test were conducted separately and analyzed. The experiments were done throughout the day from 8.00am to 8.00am and the temperature variations and the heat transfer rates are analyzed.

IV. RESULTS AND DISCUSSIONS

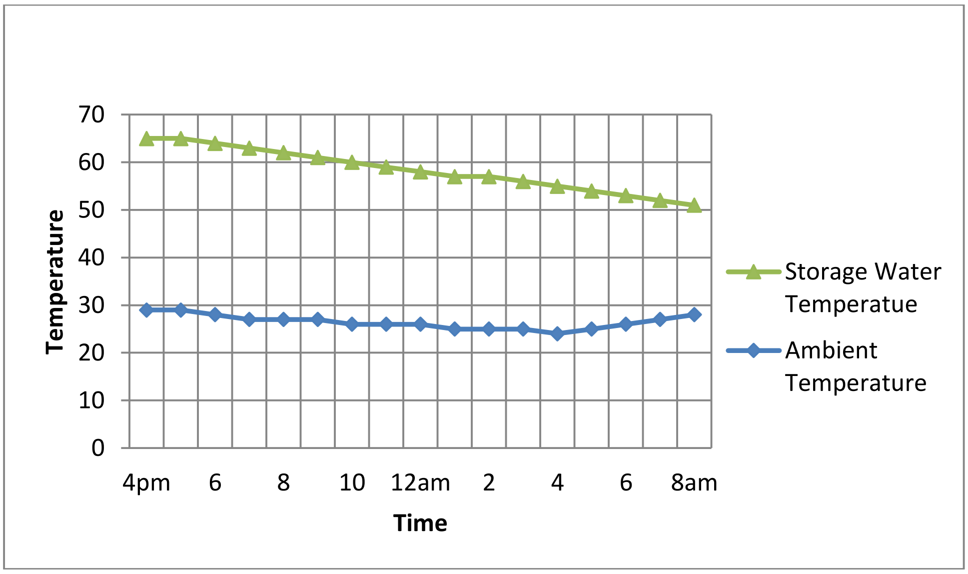
1. PERFORMANCE OF THERMO SYPHON SYSTEM.



The collector performed well in the passive circulation mode by achieving a storage water temperature of 59°C. The maximum temperature obtained by the collector is 86°C at 12.30pm and the maximum temperature obtained for the storage water is at 3.30pm such as the thermo syphon effect is continuing till 3.30pm. After then the system is not performed well due to the inadequate solar radiation to maintain the collector temperature.

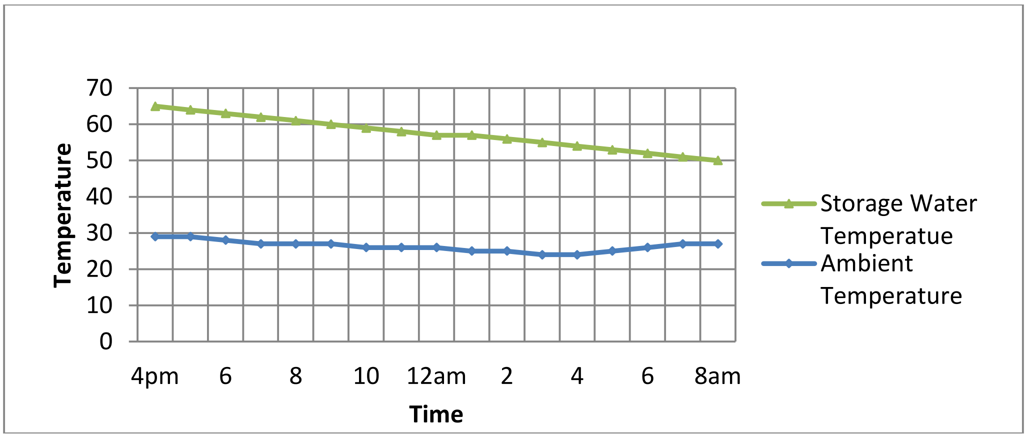
2. PERFORMANCE OF SWH WHILE USING PCM IN CU TUBE.

The copper tubes were used for the encapsulation of 55gram paraffin. The solidifying temperature of paraffin helps the storage water to stay at 57° C for 75 to 80 minutes due to its higher thermal conductivity properties. The temperature obtained in the morning 8.00am is 51°c and is sufficient for the domestic applications



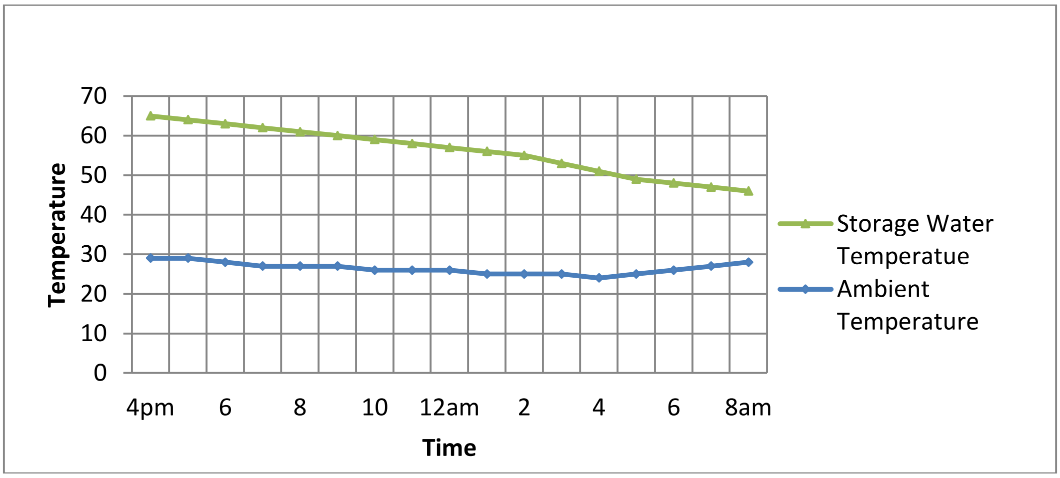
3. PERFORMANCE OF SWH WHILE USING PCM IN STEEL TUBE.

The paraffin of 77gram is encapsulated in the curved steel tubes and the solidifying temperature of wax helps to stay the storage water at 57° C for a period of 55 to 60minutes.The temperature of storage water is decreased slightly in the beginning and then it reaches uniform. This may be due to the higher thickness of tube and the low thermal conductivity property. The temperature obtained at 8am is 50° C which is sufficient for the domestic applications.



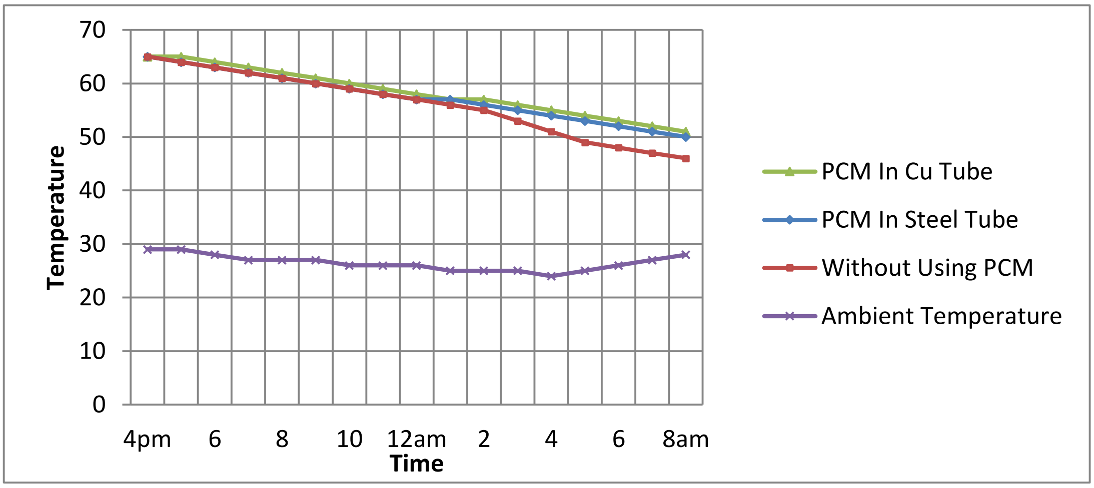
4. PERFORMANCEOF SWH WITHOUTUSING PCM.

The performance of the system without PCM is also analyzed for comparing it with the PCM geometries. The temperature maintained is 65ºC for the experiment and the temperature obtained in the morning is 46ºC.



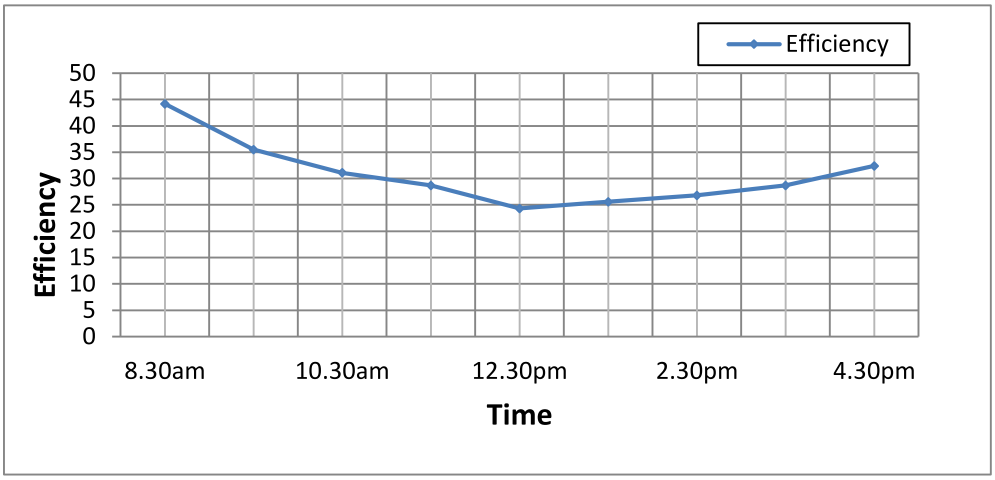
5. PERFORMANCE COMPARISON.

The PCM encapsulations in different geometry were studied. The paraffin wax used is of 770 grams for 60 liter water. The temperature obtained for Cu tube geometry is 1ºC higher than the steel tube. The PCM performance in the experiment is proved to an achievement of 4 to 5ºC temperature than a system without PCM. By the application of PCM, the storage water temperature of 57ºC is maintained constant for 55 to 60 Sec.The PCM in the copper tube geometry shows more effective. The temperature obtained without the use of PCM is 46ºC and by using PCM, a temperature range of 50 to 51ºC is obtained.



6. EFFICIENCY ANALYSIS WITH TIME

The efficiency v/s Time of the flat plate collector is plotted. The efficiency of the collector decreases with the increase in temperature. As the temperature increases, the losses also increases thus by the efficiency decreases.



For better melting and solidification, the cylindrical tubes or spherical capsules of diameter below 10mm and low wall thickness below 1mm should be effective to be experimentally analyzed. By introducing small metallic strips in the tube or sphere cavity can improve the thermal conductivity.

The present setup is fabricated with cost effective materials for the domestic applications. By using nickel – chromium based black enamel coating; the reflection losses can be minimized. The heat loss can be further minimized by the application of glass wool insulation to the storage tank. The thermo syphon effect can further improved by increasing the head of the storage tank.

V. CONCLUSION

The solar water heater with phase change material is experimentally analyzed and the various parameters werestudied.The thermo syphon effect is a major advantage to the domestic solar water heatersystem; otherwise an additional electrical energy source is needed for the active circulation of the heat transfer fluid. The thermo syphon effect can further improved by increasing the head of the system. The performance depends on the collector location, collector tilt, wind velocity, and the solar time.

The performance of paraffin wax in different geometries isstudied.The PCM can improve the performance of solar water heater. The PCM with in the Copper tube is more effective than the steel tube. The work is done with 770 gram of PCM.If the amount of PCM increases, the performance also increased.

The temperature variations were obtained throughout the testing period due to the variations in the incident solar insolation. The performance of the collector should be increased in a clear sunny day.

VI. REFERENCES

[1] G.D Rai,Non-Conventional Energy Sources, Fifth ed., KhannaPublishers, New Delhi, 2011.
[2] D.P.Kothari, K.C.Singal, KakeshRanjan, Renewable Energy Sources and Emerging Technologies, Seconded.,PHI Learning Private Limited, New Delhi-2011.
[3] G.D Rai, Solar Energy Utilization, Fifth ed., KhannaPublishers, New Delhi, 1999
[4] KingaPielichowska, Krzysztof Pielichowski, Phase change materials for thermal energy storage, Progress in Materials Science 65 (2014) 67–123
[5] Prabhu P.A., Shinde N.N, Prof. Patil P.S, Review of Phase Change Materials For Thermal Energy Storage Applications, International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 3(2012) ISSN: 2248-9622
[6] Nosa Andrew Ogie, IkponmwosaOghogho, Julius Jesumirewhe, Design and Construction of a Solar Water Heater Based on the Thermo syphon Principle Ashdin Publishing Journal of Fundamentals of Renewable Energy and Applications Vol. 3 (2013), Article ID 235592, 8 pages
[7] B. R. Vijay Prithiv, R. Prabakaran, R. Sukumar,Dr. A. Rajendra Prasad, Heat Enhancement of Domestic Solar Water Heater using PCM Filled Thin Tubes, ISR National Journal of Advanced Research in Mechanical and Production Engineering and Development Volume: 1 Issue: 1 08-May-2014.
[8] B. Kanimozhi, B. R. Ramesh Bapu, Experimental Study of Thermal Energy Storage in Solar System Using PCM, Transaction On Control And Mechanical Systems, Vol.1, No.2, Pp. 87-92, Jun., 2012.
[9] Vikram D, Kaushik S, Prashanth V, Nallusamy N, An Improvement in the Solar Water Heating Systems using Phase Change Materials, Proceedings of the International Conference on Renewable Energy for Developing Countries-2006.
[10] I.Al-Hinti, A. Al-Ghandoor, A. Maaly, I. Abu Naqeera, Z. Al-Khateeb, O. Al-Sheikh,Experimental investigation on the use of water-phase change material storage in conventional solar water heating systems,Energy Conversion and Management 51 (2010) 1735–1740
[11] 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), Article ID R120314.
[12] Hari. R, Viswanathan. E, Dr. Suresh. P. R, Enhancement of Thermal Conductivity of a PCM Based Energy Storage System, International Journal of Emerging Technology and Advanced Engineering, (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 10, October 2013)

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ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

[13] Mohammad Ali Fazilati, Ali Akbar Alemrajabi,Phase change material for enhancing solar water heater, an experimental approach, Energy Conversion and Management 71 (2013) 138–145

[14] M.H. Mahfuz, M.R. Anisur, M.A. Kibria, R. Saidur, I.H.S.C. Metselaar, Performance investigation of thermal energy storage system with Phase Change Material (PCM) for solar water heating application, International Communications in Heat and Mass Transfer 57 (2014) 132–139

[15] M.S. Hossain, R. Saidur, H. Fayaz, N.A. Rahim, M.R. Islam, J.U. Ahamed, M.M. Rahman, Review on solar water heater collector and thermal energy performance of circulating pipe, Renewable and Sustainable Energy Reviews 15 (2011) 3801–3812

[16] Abdullah Y. Usmani and NaiemAkhtar,EXISTING CORRELATIONS OF TOP HEAT LOSS FACTOR OF FLAT PLATE SOLAR COLLECTORS AND IMPACT ON USEFUL ENERGY,International Journal of Emerging Technology and Advanced EngineeringVolume 3, Special Issue 3(2013), 607-612, ISSN 2250-2459.

[17] Agarwal V K and Larsen D C. (1981). Calculation of top heat loss coefficient of a flat plate collector. Solar Energy, 27:69-71