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Thermal Energy Storage in Solar Water Heating System by Using Paraffin Wax P- 60

[1] Mr. Vaibhav B. Patil, [2] Mr. Manoj P. Undure, [3] Mr. Avesahemad S.N. Husainy, [4] Mr.Vinay S. Killedar, [5] Mr. Rohan R. Magdum
[1], [2], [5] U.G .Student, [3], [4], Faculty,
[1] – [5] Mechanical Engineering Department, Sharad Institute of Technology College of Engineering, Yadrav

Abstract:-- **Conventional energy sources are exhausted day by day. Hence the time has come to switch over this problem and produce environment friendly renewable energy sources. Sun is abundantly available with us. There are 'n' numbers of application of solar energy like solar water heating, solar drying, solar distillation, solar pond, wind mill etc. But limitation of solar energy is, it is only available in day time. Hence efficiency of solar application is low. In order to improve the efficiency of solar application thermal energy storage is a best method. In solar water heating application thermal energy storage is very effective. In solar water heating thermal energy storage can be done by using PCM like paraffin wax and sodium thiosulphate. Paraffin wax absorbs heat energy from solar water heater during day time in the form of latent heat and dissipates this energy when sun rays are not available. This energy storage fulfills the gap between the energy source, the sun, and the application. So the thermal energy storage is essential in the solar water heating system.**

I. INTRODUCTION

Energy is broadly classified into two main groups: Renewable and Non-renewable. 'Renewable Energy' is an energy which is generated from natural sources i.e. sun, wind, rain, tides; and is available in abundance. The peak solar radiation occurs near noon, but the peak heating demand is in the late evening or early morning when solar radiation is not available. Thermal energy storage provides a reservoir of energy to adjust this mismatch and to meet the energy needs at all times. The present work has been undertaken to study the feasibility of storing solar energy using Phase Change Materials (PCMs) and utilizing this energy to heat water for domestic purposes during nighttime. The system consists of two simultaneously functioning heat-absorbing units. One of them is a solar water heater 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, supplies hot water during the night. The storage unit utilizes small cylinders, made of aluminum, filled with paraffin wax as the heat storage medium. It also consists of a Solar Collector to absorb solar heat. At the start of the day the storage unit is filled with water completely. This water is made to circulate between the heating panel (Solar collector) and the PCMs. 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. The heat is recovered from the unit by passing water at room temp through it. As water is drawn from the storage tower, fresh water enters the unit disturbing the thermal equilibrium, causing flow of heat from PCM to the water. Solar heating system is one of the most wide used solar energy systems which can replace those high energy price ratio heating systems that rely on electricity or coal etc. The phase change material releases the stored heat at night to heat the floor as well as the room. The storage of thermal energy by using the latent heat of the material is called latent heat storage. Latent heat defined as the amount of heat absorbed or released during the material phase change from one phase to another phase. There are two known types of latent heat which are latent heat of fusion and latent heat of vaporization. Each material has its phase change at different temperature. The main drawback of most of the phase change materials is their low thermal conductivity that decreases the heat transfer rate. The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. **[1]** The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. This paper also summarizes the investigation and analysis of the available thermal energy storage systems incorporating PCMs for use in different applications.

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II. LITERATURE REVIEW

1. B. Kanimozhi, and B. R. Ramesh Bapu [2], They give review the heat transfer enhancement techniques are required for many latent heat thermal energy storage system; various methods are proposed to enhance the heat transfer in latent heat thermal energy storage system, such as metallic filters, metal martix structures and finned tubes were used to improve thermal conductivity of phase change materials. This paper presents work to analyze the application of the PCM in thermal energy storage systems, and the enhancement of the heat transfer from the solar tank to the PCM storage tank. PCM materials and their performance of charging and discharging of a storage tank were tested experimentally.

2. Thomas Hasenohrl, This paper briefly discusses the physical reason for this property and some important applications of PCMs. Moreover, the major advantages and drawbacks of salt hydrates and paraffins used as PCMs and some solutions to cope with the low thermal diffusivity of paraffins are presented.

3. Thirugnanam.C, Marimuthu.P [3], A significant amount of heat is wasted in manufacturing process, electricity generation, chemical and industrial process. Recovery and reuse of this energy through storage can be useful in conservation of energy. In the present study, experiments were performed for two different mass flow rates and inlet temperature of heat transfer fluid (HTF) is maintained at constant in charging process.

4. Kondakkagari Dharma Reddy, Pathi Venkataramaiah, Tupakula Reddy Lokesh [4], The continuous increase in the level of greenhouse emissions and the rise in fuel prices are the main driving forces behind efforts to more effective utilization of various sources of renewable energy. Energy storage units can be used to reduce energy consumption by using available waste heat or alternate energy sources. This also leads to saving of primary fuels and makes the system more cost effective by reducing the wastage of energy. The energy storage can also even out the mismatch between energy supply and consumption and thereby helps in saving capital costs.

5. Mohammed M. Farid, Amar M. Khudhair, Siddique Ali K. Razack, Said Al-Hallaj [5], Latent heat storage is one of the most efficient ways of storing thermal energy. Unlike the sensible heat storage method, the latent heat storage method provides much higher storage density, with a smaller temperature difference between storing and releasing heat. This paper reviews previous work on latent heat storage and provides an insight to recent efforts to develop new classes of phase change materials (PCMs) for use in energy storage. Three aspects have been the focus of this review: PCM materials, encapsulation and applications. There are large numbers of phase change materials that melt and solidify at a wide range of temperatures, making them attractive in a number of applications.

Limitations of Solar Water Heater

- Storage capacity is less.
- Capacity changes if more hot water is needed.
- Constant hot water at specific temperature is difficult to Obtain. .
- Variation in temperature is observed when cold water is added.
- Efficiency of solar water heater is less in rainy season.

III PARAFFIN WAX (PHASE CHANGE MATERIAL)

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 storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. PCMs are classified as latent heat storage (LHS) units. PCMs latent heat storage can be achieved through solid-solid, solid-liquid, solid-gas and liquid-gas phase change. However, the only phase change used for PCMs is the solid-liquid change. The PCM continues to absorb heat without a significant raise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. They store 5 to 14 times more heat per unit volume than conventional storage materials such as water, masonry, or rock.

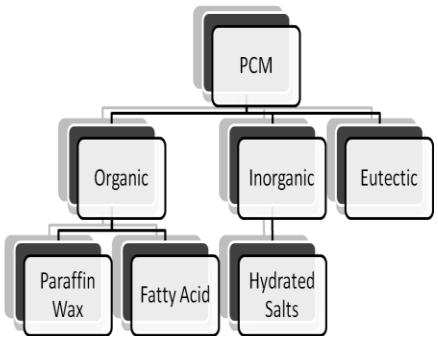

Chart No1. Classification of Phase change material

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Fig.1. Paraffin wax

Selection Criteria of P.C.M. (Paraffin)

- Melting Point of wax
- Latent Heat of wax
- Type of fluid to be handled
- Heat dissipation rate
- Density of material
- Thermal conductivity of material
- Cost consideration
- Thermal and Physical properties of Material

Physical properties of Paraffin P-60

Properties	Values
Melting-point	50ºC
latent heat	145 kJ/kg
Viscosity	1.9 mm^2/s
Density	1.412 g/cm^3
specific heat capacity – solid	2.1 kJ/kgK
specific heat capacity – liquid	2.4kJ/kgK
coefficient of thermal conduction – liquid	0.15W/mK

Table No. 1 properties of Paraffin

The advantages of using paraffin wax

1) It freezes without much super cooling.
2) It has ability to melt congruently.
3) It has self nucleating properties.
4) It is chemically stable.
5) It has high heat of fusion.
6) It is safe and non reactive.
7) It can be recycled easily

Application of PCM in water heating

PCM can be used in solar water heater, to increase its efficiency based on following principle:-During day time, the raised hot water which absorbs heat energy from Sun will be stored in tank. When tank is partially filled by PCM, the PCM will start to melt by absorbing energy from hot water. Thus PCM get charged during day time. In the evening or night, due to absence of solar energy temperature of hot water reduces. When temperature goes below 60ºC paraffin wax will start to freeze. During its freezing it will give its latent heat to water, and maintains water's temperature. This increases reliability of solar water heater by allowing availability of hot water in the night also.

IV EXPERIMENTATION

We design solar water heating system for 50 lit.capacity.At first we take the reading of hot water from solar water heater without using PCM kit for 3 days. After that we take the readings with using PCM kit for 3 days. The procedure is as follows, Cold water is supplied to the storage tank of solar water heater. The working of evacuated solar water heater is based on a natural principle 'Thermo siphon'. Due to which the hot water is stored in the storage tank. The hot water gives it's heat to PCM kit. Therefore the temperature of PCM increases by storing heat. After each hour we taken the readings of hot water in the collector (T1), hot water in the storage tank (T2), temperature of PCM (T3) and ambient temperature (T4) by using thermocouples and indicator. The solar intensity was measured using solar intensity meter having accuracy of about ± 10W/m^2. At evening we discharge the hot water and fill the cold water in the storage tank by maintaining the required flow rate. Record the fresh water temperature. Now the heat stored in the PCM gives it's heat to the cold water. At this instant we take the readings after each 10 minutes until the system is stable. When the temperature of water in the storage tank and PCM gets equal, then we take the readings after each hour. The experiment was repeated for 3 days and the readings are taken.

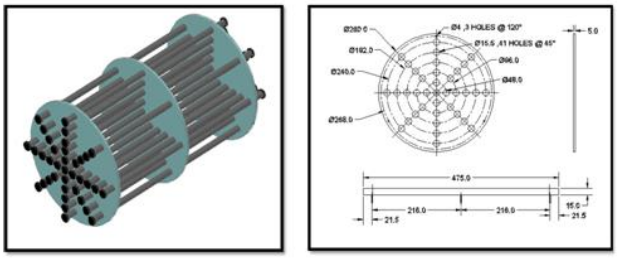

Fig.2. Inner Kit of P.C.M.

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Specification of tank and kit

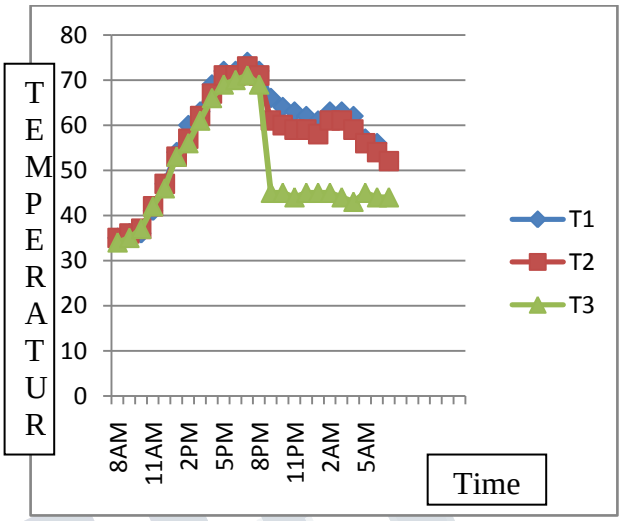
Content	Values
Volume Of Tank	50 Lit.
Volume Of Aluminium Pipes	88312.5cubic-mm.
Total No. Of Aluminium Pipes	35
Capacity Of Collector	5011659.8cubic-mm
Capacity Of Cold Water Tank	75 Lit.
Amount Of Wax Used	2.8 kg
Total Wax Used In Each Al Pipe	69 gm
Weight Of Aluminium Pipe	46 gm
Weight Of Rubber End Cap	1.5 gm
Weight Of Foam Plate	80 gm
Weight Of Wax in each Al Pipe	69 gm
Weight Of Hot Water Tank	8 kg

Table No. 2 Specification

Trial on Solar water Heater:-

T1 = Temperature of Paraffin Wax
T2 = Temperature of Hot Water Tank
T3 = Temperature of Collector

Time	T1	T2	T3
9 am	36	35	36
10 am	37	37	36
11 am	42	42	41
12 am	47	46	47
1 pm	53	53	54
2 pm	57	56	60
3 pm	62	61	63
4 pm	67	66	69
5 pm	71	69	72
6 pm	71	70	72
7 pm	73	70	74
8 pm	71	69	72
9 pm	61	45	66
10 pm	60	45	64
11 pm	59	44	63
12 am	59	45	62
1am	58	45	61
2 am	61	44	63
3 am	61	43	63
4 am	59	45	62
5 am	56	44	57
6 am	54	44	56
7 am	52	47	52
8 am	47	46	46



Graph.1. Time vs Temp

Comparison between temp with and without kit

Time(hrs)	Temp (without kit)	Temp(kit)
8A.M.	34	34
9 A.M.	36	36
10 A.M.	36	36
11 A.M.	42	42
12 Noon	47	47
1 P.M.	53	53
2 P.M.	57	57
3 P.M.	62	62
4 P.M.	67	67
5 P.M.	71	71
6 P.M.	71	71
7 P.M.	71	71
8 P.M.	**71**	**71**
9 P.M.	42	61
10 P.M.	42	60
11 P.M.	41	59
12 Mid-Night	40	59
1 A.M.	40	58
2 A.M.	40	58
3 A.M.	39	56
4 A.M.	39	54
5 A.M.	39	52
6 A.M.	38	51
7 A.M.	37	49

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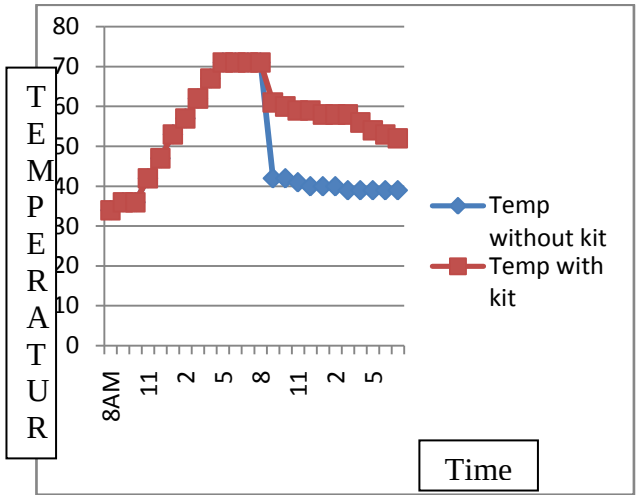

Graph.2. Time vs Temp

V CALCULATION

Content	Temp.^{0}C	Temp. ^{0}C
AVG (before water changed)	55.23	55.23
MAX Temp.	71	71
MIN Temp.	34	34
AVG (after water changed)	39.90	57.09
MAX Temp.	42	61
MIN Temp.	38	52

VI. RELIABILITY CALCULATIONS

Flat plate collectors can only heat water up to 170-180 degrees Fahrenheit, which means there is very little risk of overheating. Evacuated tubes, on the other hand, can heat water to well over 250 degrees. For this reason, they are much more likely to overheat than flat plates, and you need to be more concise with your design. Evacuated tubes are also used more in colder climates because they are more efficient than flat plates in extremely cold temperatures.

Readings of Solar Water Heater working on latent heat.

Time(hr)	Hot water tank temp.
9am	36
10 am	37
11 am	42
12 am	47
1pm	53
2 pm	57
3 pm	62
4 pm	67
5 pm	71
6 pm	71
7 pm	73
8 pm	71
9 pm	61

Formula for Reliability:

$$1 - \frac{Bm - Ba}{Bm}\%$$

Where,
Bm = Maximum temperature.
Ba = Average temperature.
Bm = 73^{0}C

$$Ba = \frac{36+37+42+47+53+57+62+67+71+71+73+71+61}{13} = 57.53^0C$$

$$= 1 - \frac{73-57.53}{73}\%$$

Ba =78.80%

VII. CONCLUSION

There are many sources available to heating the water. But the most convenient method of heating water is solar energy, because of its availability. In ordinary solar water heater works on the principle of sensible heating; but our solar water heater works on the principle of latent heat storing by Phase Change Material (P.C.M.) i.e. Paraffin Wax Solar water heating system plays an important role in sustainable energy management in Indian households as well as worldwide. This project will also help to find out the suitable PCM and provide the various designs for solar water heating systems to store the solar thermal energy. It is more advantageous where the space restriction limits larger

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thermal storage units in direct gain or sunspace passive solar system & more hot water is obtained with same capacity.

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Fig.3. Experimental Set-up

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