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Study And Fabrication of Thermal Energy Storage System for Solar Water Heater

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ABSTRACT: Solar water heating systems are common in recent time for obtaining the hot water for bath as well as for other household and industrial work. But this is useful on day time because solar energy is available only on day time for few hours. To get hot water when solar radiations are not available it is necessary to store the heat energy extracted during day time and uses that energy to heat the water. The present work has been undertaken to study the feasibility of storing solar energy using phase change materials and utilizing this energy to heat water for domestic applications during night time. This ensures that hot water is available throughout the day. The storage system consists of two simultaneously functioning heat-absorbing units. One of them is a solar water heater and the other a heat storage unit consists of storage medium . The solar water heater functions normally and supplies hot water during the day. The storage unit stores the heat in storage medium during the day and supplies hot water during the night and overcast periods. They can be used for equalization of day & night temperature and for transport of refrigerated products. In the proposed project heat of fusion of storage medium is used for heating water during night. The system is proposed to achieve the temperature of 60^0C at off time. The system has an ability to achieve the temperature of 98^0C.

Keywords: Thermal energy storage, Phase change materials, solar energy, sensible heat storage

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I. INTRODUCTION

Thermal energy storage (TES) systems provide alternative solutions to benefit water heating in order to save the energy. Thermal storage is used to store the heat energy therefore it called as thermal energy storage (TES), energy during the processing is stored in the storage material and it is used later on when no heat energy is available. Thermal storage is used to store heat energy & retrieve this energy when heat energy is not available to run the system. Solar water heating systems are common in obtaining hot water for household and industrial work. But this is useful on day time because solar energy is available only on day time for few hours. To have hot water when solar radiations are not available it is necessary to harness and stores the solar energy during day time and uses it in later part of the day. Solar energy has a great potential to serve as an alternative source of energy and to save the fossil fuel, the only need to harness it in proper way. Thermal energy stored in the form of sensible heat storage (SHS) or latent heat storage (LHS). To store the same amount of energy, significantly larger quantities of a storage medium is required for SHS in comparison to LHS. There are many situations where available energy is wasted because due to wrong management. All such methods involve high capital investment. Efforts of rational and effective energy management as well as environmental considerations increased the interest in utilizing renewable energy sources, especially solar energy. The work described below falls within an area of international interest as it deals with energy saving, the efficient and rational use of available resources and the optimum use of renewable energies.

This work provides a survey of studies dealing with TES using sensible and phase change materials. The material in this review has been arranged within the main areas of work:

• Energy storage media
• Heat transfer analysis
• Applications

Thermal storage bridge the gap between energy availability and energy use and therefore it has the potential to achieve considerable environment as well as economic benefits for many heating and cooling application [6].Useful classification of the substances used for TES is shown in Figure.1

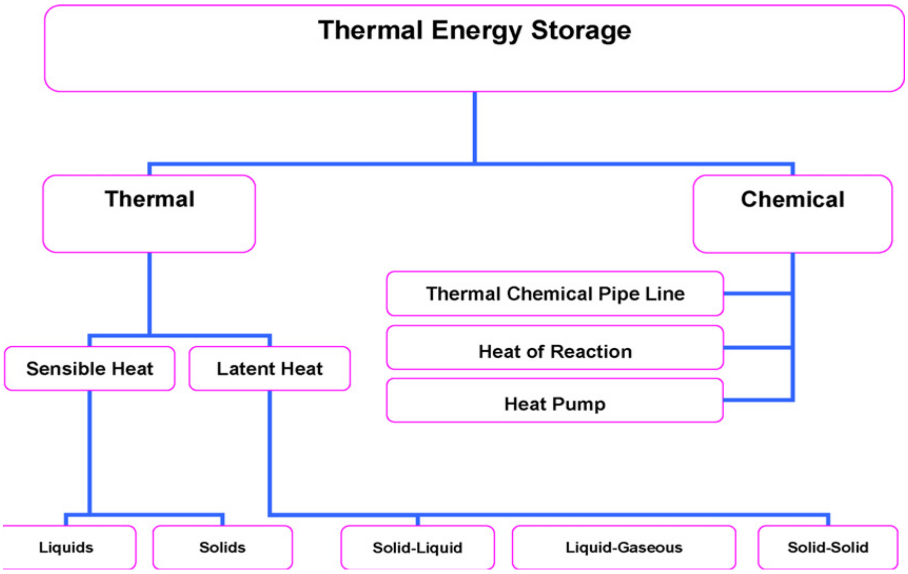

Fig.1.. Different types of thermal storage of solar energy

A) Types of thermal energy storage methods

i) Sensible heat storage: In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a solid or liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging. The amount of heat stored depends on the specific heat of the medium, the temperature change and the amount of storage material

$$Q=\int_{Ti}^{Tf} mCpdT \quad [1]$$

$$Q=mCp(T_f - T_i) \quad [2]$$

The sensible heat storage capacity of some selected solid–liquid materials is shown in Table 1. Water appears to be the best SHS liquid available because it is inexpensive and has high specific heat. However above 100 ^{0}C, oils, molten salts and liquid metals, etc. are used. For air heating application rock bed type storage materials are used [4].

ii) Latent heat storage: Latent heat storage (LHS) is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. The storage capacity of the LHS system with a PCM medium is given by [4]

$$Q=\int_{Ti}^{Tm} mCpdT + ma_m\Delta h_m + \int_{Tm}^{Tf} mCpdT$$

$$Q=m[Csp(T_m - T_i) + a_m h_m + C_{lp}(T_f - T_m)$$

Table no. 1.:- Properties of liquid media storage for solar water heating system[8]

Medium	Fluid Type	Temp. Range (°C)	Density Kg/m3	Heat Capacity (J/kg.K)	Thermal conductivity (w/mk)
Water	-	0 to 100	1000	4190	0.63 at 38 ^{0}c
Water-Ethylene Glycol 50/50	-	-	1050	3470	-
Ethylene Glycol	-	-	1116	2382	0.249 at 20^{0}c
Hitec	Molten salt	141 to 540	1680	1560	0.61
Engine oil	Oil	Up to 160	888	1880	0.145
Draw salt	Molten salt	220 to 540	1733	1550	0.57
Lithium	Liquid salt	180 to 1300	510	4190	38.1
Sodium	Liquid salt	100 to 760	960	1300	67.5
Ethanol	Organic liquid	Up to 78	790	2400	-
Propanol	- do -	Up to 97	800	2500	-
Butanol	- do -	Up to 118	809	2400	-

After studying the characteristics and properties of storage medium.For liquid storage medium required high specific heat and density to store more heat (sensible heat). Water has best properties than other. Water can store more heat than other . problem is that it vaporized after 100^0c . It is limited to the system which has initial temperature less than 100^0c .
For solar thermal energy storage water and engine oil a suitable medium to store heat energy both having good conductivity and specific heat.

II. COUNSTRUCTION AND COMPONENTS OF SOLAR WATER HEATING SYSTEM

I. Solar Collector

Solar collectors are the key component of active solar-heating systems. They gather the sun's energy, transform its radiation into heat, then transfer that heat to a fluid (usually water or air). The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. There are a large number of solar collector designs that have shown to be functional. These designs are classified in two general types of solar collectors: [9]
i)Flat-plate collectors–the absorbing surface is approximately as large as the overall collector area that intercepts the sun's rays.
ii) Concentrating collectors – large areas of mirrors or lenses focus the sunlight onto a smaller absorber.

Flat-plate collectors

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. Fig.no.2.represent a typical liquid flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 90°C. Flat-plate collectors are used for residential water heating and hydronic space-heating installations. Figure shows a schematic drawing of the heat flow through a collector. The question is, how to measure its thermal performance, i.e. the useful energy gain or the collector efficiency thus it is necessary to define step by step the singular heat flow equations in order to find the governing equations of the collector system. Flat plate solar collector may divide into main significations based on the types of heat transfer fluid used.

Used for heating water collector is heating water and non-freezing aqueous solution occasionally for non-aqueous heat transfer fluid. In this system, we used liquid heating collector [9]. Components of flat plate collector are shown in fig.no.2 as follows:-
(a) ***Absorber Plate***: Its purpose is to absorb the solar radiation as much as possible and to transfer the heat to the coolant. In this study, the absorber plate is of length: 122 cm, width 60 cm and is made of 22 gauge GI sheet. The plate is coated by a non-selective coating with a view to improve its absorptivity. Several thermocouples are attached to the plate from the bottom to get spatial temperature distribution
(b) ***Tubes*** : Three equally spaced copper tubes of 0.5inch diameter are brazed to the plate in pre-machined semicircular troughs and gap between troughs and tubes are filled with molten lead. Thermocouple locations are also machined in the tubes to measure the coolant temperature during the experiment.
(c) ***Thermal Insulation***: The absorber plate-and-tubes assembly is housed in a wooden box ($1*2m^2$) having adequate clearance for adding insulation necessary to prevent the side and bottom heat losses from the collector. Wooden chips and glass wool are used in this study for this purpose.
(d) ***Glazing*****:** Two 4-mm thick glass sheets are used as glazing for both the collectors. These are provided to reduce top losses from the collectors.

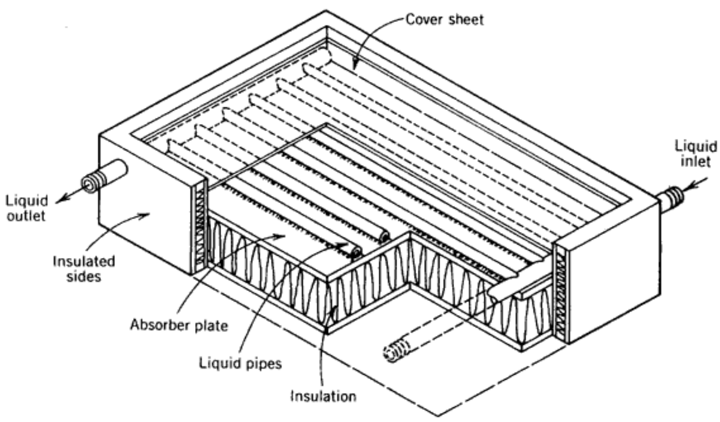

Fig. 2 A typical liquid Flat Plate Collector[9]

Fig: 3 -Prototype of solar flat plate collector

GI tubes and/flexible tubing are connected with the water tank and/or storage tank to complete circulation of the working fluid in the thermosyphon. The exit tubing for vapor/hot water from the collector is also insulated to prevent heat losses. The vapor tube has provisions to visualize the flow of vapor. The wooden box containing flat-plate collector is supported in a frame that can be tilted from 20 o c to $_{40}0$ c. Specification of fig.no.3.1.2 Prototype of solar flat plate collector are given below.

Outer box:
Material plywood,
Size: L=7'', W=3"10' , H=6'

Inner box:
Material- G.I. sheet,
Size: L=6"8', W=3"6' ,H=4'

Tubing frame:
Material- copper,
Size: D=0.5'(inch), L=25m
No. of tubes=20
Angle of Thermosyphon =30 (to the north –east position)

II) Storage Tank

Storage tank having capacity of 30 liter contains the liquid storage medium and secondary coil shown in fig 4.prototype of storage tank. Various components of storage tank shown in fig.no.5 schematic of storage tank. The tank is also insulated with PUF to prevent heat loss of the environment. A thermometer is fitted there to measure the temperature of tank water after a regular interval. Cold water supply continuously to the collector form the tank and water is heated in collector .this hot supply to the tank through the outlet of collector. This is close loop system. In storage tank heat exchanger coil is fitted to exchange the heat between primary fluid to the secondary fluid.

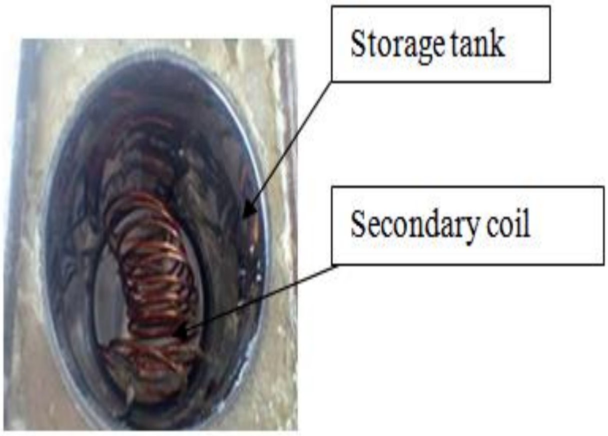

Fig.4- Prototype of storage tank

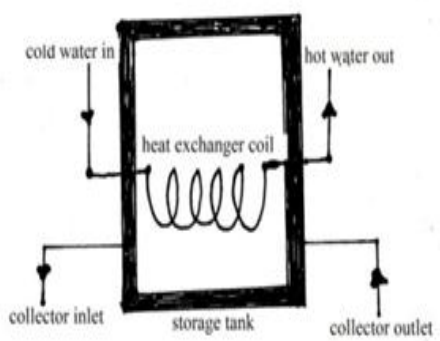

Fig.5 -Schematic of storage tank

Storage is actually achieved by thermal stratification that is water of high temperature than to overall mixing temperature can be extracted at the top of the container and water of lower temperature than the mixing temperature can be drawn off from the bottom to make use even of short insolation periods and running the collector at a higher efficiency. Due to the heat losses from the surface of the storage tank, the temperature of water near the vertical walls is lower, leading to natural convection currents that destroy the temperature layers.

III) Heat Exchanger

"Heat exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs." In heat exchangers the temperature of each fluid changes as it passes through the exchangers and hence the temperature of the dividing wall between the fluids also changes along the length of exchanger. Through the heat exchanger coil pass the secondary fluid (water).At the one end of coil supply continuously cold water and it take the heat from primary storage fluid in tank. Where heat is exchange between primary fluids to secondary fluid. Heat exchanger coil (secondary coil) shown in fig 6 given below.

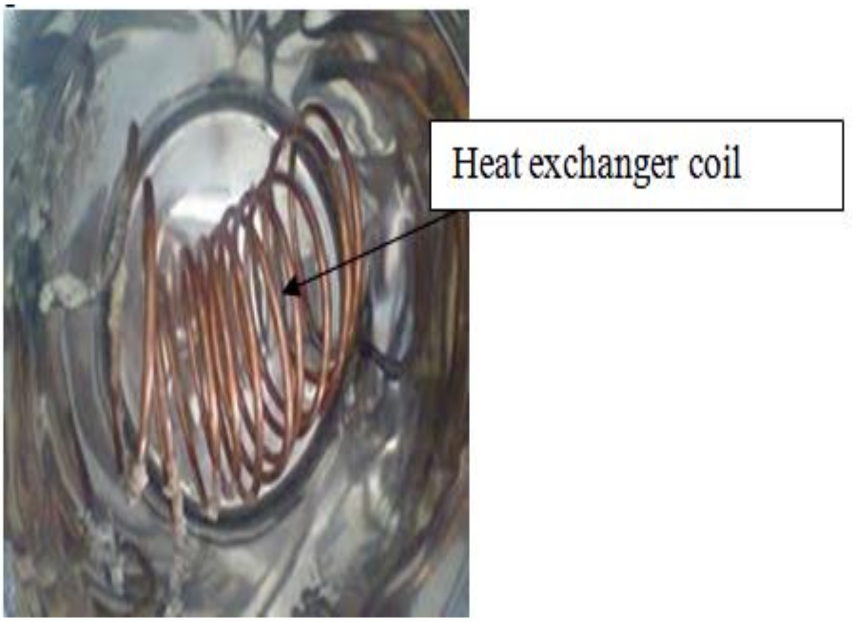

Fig. 6- Prototype of heat exchanger coil

III. SEPECIFICATION AND WORKING OF SOLAR THERMAL ENERGY STORAGE SYSTEM

Following are the components with the specification required for the construction of solar water heating system shown in table no.2 given below.

Table no. 2 - Specification of Components

Sr.No	Components	Qty.	specification
1	Solar collector	01	1*2 m^2
2	Temperature indicator	03	0^0c to 250^0c
3	Valves	01	Flow control valve
4	Copper tubes	01	25m
5	Storage tank(steel drum)	01	30 lit
6	water pump	01	8 HP
7	glass	01	4 mm thickness
8	water	30 lit	Liquid storage medium
9	Oil	30 lit	Liquid storage medium
10	Glass wool	8 kg	Insulating material
11	PUF	5 lit	Insulating material

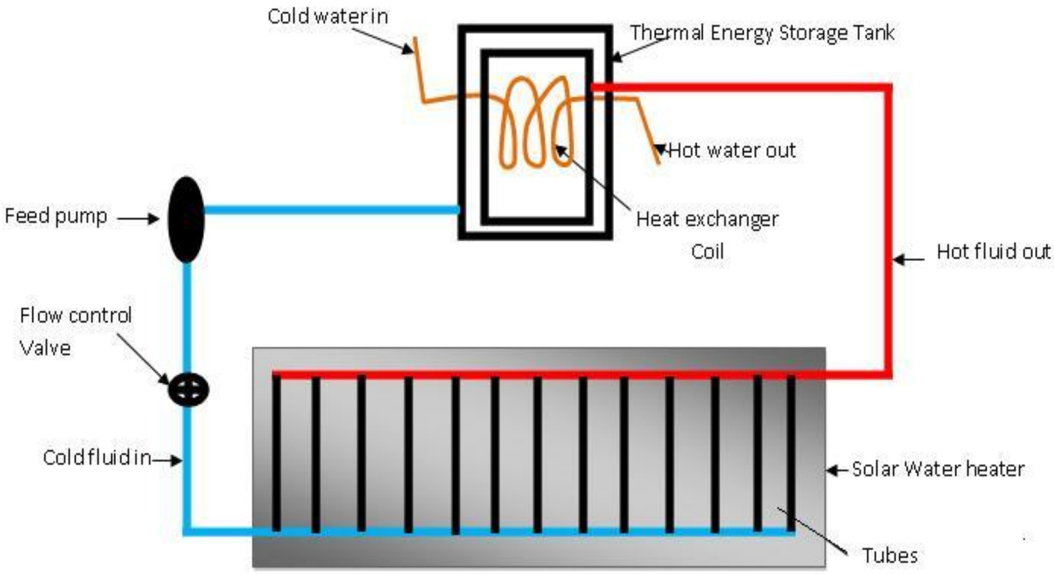

Fig. . Schematic of solar Thermal Storage system

Fig. schematic of solar thermal storage system represent the working of solar water heating system. It consist of solar flat collector or evacuated tube collector with fixed position. It used as solar hot water panel to generate solar hot water. Collector inlet is attached to the inlet of storage tank. At the inlet pump is required to circulate the wate/oil in collector panel. After the feed pump flow control valve is attached to control the flow of water/oil. Outlet of collector through which hot water/oil pass is attached to the outlet of storage tank. Storage tank is placed before feed pump having capacity of 30liter. Outer portion of storage tank is insulated with PUF to prevent the heat loss. Heat exchanger coil is placed inside the storage tank through which secondary fluid is flow. This cylindrical storage tank system is closed loop system with collector.

Solar hot water systems function as heat exchangers. They receive solar radiant energy and transfer it to the flowing fluid. The coated plate absorbs solar radiation, converts it into heat and transfer the resulting heat to circulating water. Hot water is then supplied to the storage tank for domestic heating uses. During the sunshine hours, cold water/oil continuously supply to the collector from storage tank .solar radiation incident on collector that's why water/oil is heated and again supply to the storage tank. This cylindrical storage tank system is closed loop system. Liquid storage medium collects energy in the form of sensible heat .In storage tank heat exchanger coil is placed. Cold water (i.e. secondary fluid) is supply through the heat exchanger coil it gains the heat energy from primary fluid in storage tank. Where exchange the heat between primary fluids to secondary fluid. During off sunshine hours, the hot water is withdrawn when it is necessary.

IV.ADVANTAGES AND DISADVANTAGES

Advantages

- These systems use solar energy which is a free and renewable source of energy.
- It leads to saving of energy for water heater.
- Many countries around the world offer favorable incentives for the installation of solar water heating systems.
- Relatively good payback period, in average between 5-10 years - These systems have low maintenance costs.
- System can able to provide hot water even when solar energy is not available.

Disadvantages

- Initial investment cost is high.
- In most areas they will require electrical or gas or other fuel backup during the winter period
- Efficiency varies throughout the day.
- Heat exchanger doesn't give 100% efficiency.
- Cannot sustain the energy for longer period.

V.CONCLUSION

A sensible heat storage system containing liquid storage medium is studied and fabricated with an effective water/oil storage capacity of about 30 liters, enough to meet the needs of a family of four. The ambient temperature affects the performance of solar water heater on a minor scale in the morning hours. As the ambient temperature is less in the morning the heat transfer to the secondary fluid from primary fluid is less and hence efficiency is less.In the afternoon, due to higher ambient temperature there is more rate of heat transfer correspondingly higher efficiency. Heat storage capacity and efficiency of water is maximum as compared to oil therefore water is preferable .Hence it can be concluded that susceptibility of water is more desirable. Further Evaluation, Analysis and comparision of water & other fluid such as oil can be done in next proposed paper.

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