Fabrication and Analysis of Thermal Energy Storage System Based on Novel Phase Change Material

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Abstract- *Developing efficient and inexpensive energy storage devices is as important as developing new sources of energy. Energy storage can reduce the time between energy supply and energy demand, thereby playing a vital role in energy conservation. It improves the energy systems by smoothening the output and thus increasing the reliability. This project deals with storage of thermal energy in materials undergoing phase changes. A solar water heating system to be selected. Preferably a parabolic or flat plate collector selected when the complete parabolic or flat plate collector is fabricated. Thermal storage material like paraffin is circulated from a tank to collector and the paraffin taken back to the tank using a pump. In the circuit a metal coil of paraffin taken inside a water tank with sand and pebble bed storage.*

Keywords- solar collector, heat exchanger with water tank, pump, paraffin, paraffin tank.

I. INTRODUCTION

The continuous increase in the level of greenhouse gas emissions and the climb in fuel prices are the main driving forces behind efforts to more effectively utilize various sources of renewable energy. In many parts of the world, direct solar radiation is considered to be one of the most prospective sources of energy. The scientists all over the world are in search of new and renewable energy sources. One of the options is to develop energy storage devices, which are as important as developing new sources of energy.

The storage of energy in suitable forms, which can conventionally be converted into the required form, is a present day challenge to the technologists. Energy storage not only reduces the mismatch between supply and demand but also improves the performance and reliability of energy systems and plays an important role in conserving the energy. It leads to saving of premium fuels and makes the system more cost effective by reducing the wastage of energy and capital cost. For example, storage would improve the performance of a power generation plant by load leveling and higher efficiency would lead to energy conservation and lesser generation cost. One of prospective techniques of storing thermal energy is the application of phase change materials (PCMs). Unfortunately, prior to the large-scale practical application of this technology, it is necessary to resolve numerous problems at the research and development stage.

II. TYPES OF ENERGY STORAGE METHODS ARE GIVEN BELOW

The different forms of energy that can be stored include mechanical, electrical and thermal energy.

Mechanical energy storage

Mechanical energy storage systems include gravitational energy storage or pumped hydropower storage (PHPS), compressed air energy storage (CAES) and flywheels. The PHPS and CAES technologies can be used for large-scale utility energy storage while flywheels are more suitable for intermediate storage. Storage is carried out when inexpensive off-peak power is available, e.g., at night or weekends. The storage is discharged when power is needed because of insufficient supply from the base-load plant.

Electrical storage

Energy storage through batteries is an option for storing the electrical energy. A battery is charged, by connecting it to a source of direct electric current and when it is discharged, the stored chemical energy is converted into electrical energy. Potential applications of batteries are utilization of off-peak power, load leveling, and storage of electrical energy generated by wind turbine or photovoltaic plants. The most common type of storage batteries is the lead acid and Ni–Cd .

Thermal energy storage

Thermal energy storage can be stored as a change in internal energy of a material as sensible heat, latent heat and thermo chemical or combination of these. An overview of major technique of storage of solar thermal energy.

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. The sensible heat storage capacity of some selected solid– liquid materials. Water appears to be the best SHS liquid available because it is inexpensive and has a high specific heat. However above 100 8C, oils, molten salts and liquid metals, etc. are used. For air heating applications rock bed type storage materials are used.

Latent heat storage

Latent heat storage (LHS) is based on the heat absorption or release when a storage materialundergoes 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.

Thermo chemical energy storage

Thermo chemical systems rely on the energy absorbed and released in breaking and reforming molecular bonds in a completely reversible chemical reaction. In this case, the heat stored depends on the amount of storage material, the endothermic heat of reaction, and the extent of conversion.

Amongst above thermal heat storage techniques, latent heat thermal energy storage is particularly attractive due to its ability to provide high-energy storage density and its characteristics to store heat at constant temperature corresponding to the phasetransition temperature of phase change material (PCM). Phase change can be in the following form: solid–solid, solid–liquid, solid–gas, liquid–gas and vice versa.

In solid–solid transitions, heat is stored as the material is transformed from one crystalline to another. These transitions generally have small latent heat and small volume changes than solid–liquid transitions. Solid–solid PCMs offer the advantages of less stringent container requirements and greater design. Most promising materials are

Organic solid solution of pentaerythritol (m.p1888C, latent heat of fusion 323 kJ/kg),

Pentaglycerine (m.p.818C, latent heat of fusion216 kJ/kg),

Li_2SO_4 (m.p. 578, latent heat of fusion 214 kJ/kg)

KHF_2 (m.p. 196 8C, latent heat of fusion 135 kJ/kg).

Trombe wall with these materials could provide better performance than a plain concrete Trombe wall. Solid–gas and liquid–gas transition through have higher latent heat of phase transition but their large volume changes on phase transition are associated with the containment problems and rule out their potential utility in thermal-storage systems. Large changes in volume make the system complex and impractical. Solid–liquid transformations have comparatively smaller latent heat than liquid–gas. However, these transformations involve only a small change (of order of 10% or less) in volume. Solid–liquid transitions have proved to be economically attractive for use in thermal energy storage systems. PCMs themselves cannot be used as heat transfer medium. A separate heat transfer medium must me employee with heat exchanger in between to transfer energy from the source to the PCM and from PCM to the load. The heat exchanger to be used has to be designed specially, in view of the low thermal diffusivity of PCMs in general.

The volume changes of the PCMs on melting would also necessitate special volume design of the containers to wholes PCM. It should be able to absorb these volume changes and should also be compatible with the PCM used. Any latent heat energy storage system therefore, possess at least following three components:

(i) a suitable PCM with its melting point in the desired temperature range,
(ii) a suitable heat exchange surface,
(iii) a suitable container compatible with the PCM.

The development of a latent heat thermal energy storage system hence, involves the understanding of three essential subjects: phase change materials, containers materials and heat exchangers. A wide range of technical options available for storing low temperature thermal energy.

Thermal properties

(i) Suitable phase-transition temperature.
(ii) High latent heat of transition.
(iii) Good heat transfer.

Selecting a PCM for a particular application, the operating temperature of the heating or cooling should be matched to the transition temperature of the PCM. The latent heat should be as high as possible, especially on a volumetric basis, to minimize the physical size of the heat store. High thermal conductivity would assist the charging and discharging of the energy storage.

Physical properties

(i) Favorable phase equilibrium.
(ii) High density.
(iii) Small volume change.
(iv) Low vapor pressure.

Phase stability during freezing melting would help towards setting heat storage and high density is desirable to allow a smaller size of storage container. Small volume changes on phase transformation and small vapor pressure at operating temperatures to reduce the containment problem.

Kinetic properties

(i) No super cooling.
(ii) Sufficient crystallization rate.

Super cooling has been a troublesome aspect of PCM development, particularly for salt hydrates. Super cooling of more than a few degrees will interfere with proper heat extraction from the store, and 5–10 8C super cooling can prevent it entirely.

Chemical properties

(i) Long-term chemical stability.
(ii) Compatibility with materials of construction.
(iii) No toxicity.
(iv) No fire hazard.

PCM can suffer from degradation by loss of water of hydration, chemical decomposition or incompatibility with materials of construction. PCMs should be non-toxic, non-flammable and non-explosive for safety.

Economics

(i) Abundant.
(ii) Available.
(iii) Cost effective.

Low cost and large-scale availability of the phase change materials is also very important.

Classification of PCMs

A large number of phase change materials (organic, inorganic and eutectic) are available in any required temperature range. A classification of PCMs is given in Fig. 3. There are a large number of organic and inorganic chemical materials, which can be identified as PCM from the point of view melting temperature and latent heat of fusion. However, except for the melting point in the operating range, majority of phase change materials does not satisfy the criteria required for an adequate storage media as discussed earlier.

As no single material can have all the required properties for an ideal thermal-storage media, one has to use the available materials and try to make up for the poor physical property by anadequate system design. For example metallic fins can be used to increase the thermal conductivity of PCMs, supercooling may be suppressed by introducing a nucleating agent or a ‘cold finger’ in the storage material and incongruent melting can be inhibited by use of suitable thickness.

In general inorganic compounds have almost double volumetric latent heat storage capacity (250–400 kg/dm3) than the organic compounds (128–200 kg/dm 3). For their very different thermal and chemical behavior, the properties of each subgroup which affects the design of latent heat thermal energy storage systems using PCMs

Paraffin’s

Paraffin wax consists of a mixture of mostly straight chain nalkanes CH3–(CH2)–CH3. The crystallization of the (CH3)- chain release a large amount of latent heat. Both the melting point and latent heat of fusion increase with chain length. Paraffin qualifies as heat of fusion storage materials due to their availability in a large temperature range. Due to cost consideration, however, only technical grade paraffins may be used as PCMs in latent heat storage systems.

Paraffin is safe, reliable, predictable, less expensive and non-corrosive. They are chemically inert and stable below 500 8C, show little volume changes on melting and have low vapor pressure in the melt form. For these properties of the paraffins, system-using paraffins usually have very long freeze–melt cycle. paraffin mixtures and are not completely refined oil. The melting point of alkane increases with the increasing number of carbon atoms. Apart from some several favorable characteristic of paraffins, such as congruent melting and good nucleating properties.

They show some undesirable properties such as:

(i) low thermal conductivity,
(ii) non compatible with the plastic container and
(iii) Moderately flammable.

All these undesirable effects can be partly eliminated by slightly modifying the wax and the storage unit. Some

selected paraffins are shown in Table 2b along-with their melting point, latent heat of fusion and groups.
PCMs are categorized as:

(i) group I, most promising;
(ii) group II, promising; and
(iii) Group III, less promising.

PHYSICAL PROPERTIES OF SOME PARAFFIN'S

Paraffin a	Freezing point/range (8C)	Heat of fusion(kJ/kg)	Group
6106	42–44	189	I
P116	45–48	210	I
5838	48–50	189	I
6035	58–60	189	I
6403	62–64	189	I
6499	66–68	189	I

Manufacturer of technical Grade Paraffin's 6106, 5838, 6035, 6403 and 6499: Ter Hell Paraffin Hamburg, FRG.

Solar water-heating systems

Solar water heater is getting popularity since they are relatively inexpensive and simple to fabricate and analyzed a built in storage type water heater containing a layer of PCM filled at the bottom. During the sunshine hours, the water gets heated up which in turn transfers heat to the PCM below it. The PCM collects energy in the form of latent heat and melts. During off sunshine hours, the hot water is withdrawn and is substituted by cold water, which gains energy from the PCM.

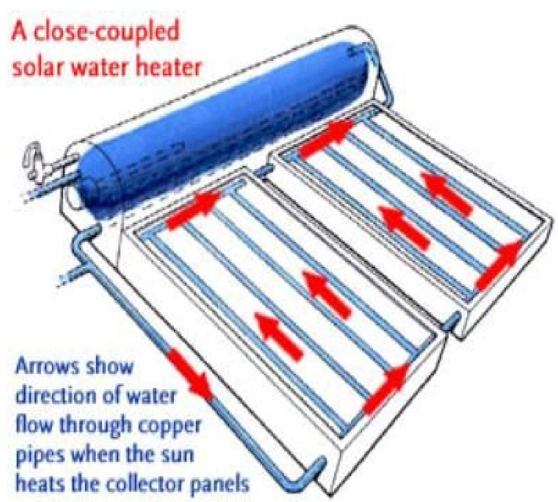
The energy is released by the PCM on changing its phases from liquid to solid. This type of system may not be effective due to the poor heat transfer between PCM and water. A cylindrical storage unit in the closed loop with a flat plate collector has been theoretically studied by **ABILASH RAJIV DHARAN.A** for its charging and discharging mode. The calculations for the interface moving boundary and fluid temperature were made by using paraffin wax (p-116) and stearic acid as phase change materials. A comparative study of solar energy storage systems based on the latent heat and sensible heat technique has been carried out to preserve the solar heated hot water.

One storage unit contained 17.5 kg paraffin wax (m.p. about 54 8C) as the storage material packed in a heat exchanger made of the aluminum tubes and another unit simply contained the water as a storage material in a GI tank.

SOLAR FLAT PLATE COLLECTOR

A solar collector is basically a flat box and is composed of three main parts, a transparent cover, tubes which carry a coolant and an insulated back plate. The solar collector works on the green house effect principle;

Solar radiation incident upon the transparent surface of the solar collector is transmitted through though this surface. The inside of the solar collector is usually evacuated, the energy contained within the solar collect is basically trapped and thus heats the coolant contained within the tubes. The tubes are usually made from copper, and the back plate is painted black to help absorb solar radiation. The solar collector is usually insulated to avoid heat losses.



Active solar paraffin heating

The main components on an active solar paraffin heating system are

Solar collector to capture the suns energy and to transfer is to the coolant medium

- A circulation system that moves the fluid between the solar collector and the storage tank
- Storage tank
- Back up heating system
- Control system to regulate the system operation

The two main types of solar paraffin heating systems are the closed loop system and paraffin the open loop system. The open loop system used paraffin as the coolant the circulates between the solar collector and the storage tank.

There are two main types of open loop system these are the drain down system and the recirculation system, the main principle behind both systems is the activation of circulation from the collector to the storage tank when the temperature within the solar collector reaches a certain value.

In the drain down system a valve is used to allow the solar collector to fill with paraffin when the collector reaches a certain temperature.

In the re-circulating system paraffin is pumped through the collector when the temperature in the storage tank reaches a certain critical value.

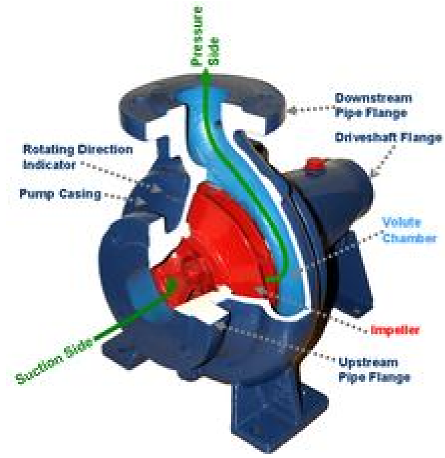
In applications where there is likely to be a temperature drop below zero degrees then it is necessary to use a closed loop system. The main difference between the open loop systems is the paraffin is replaced with a coolant which will not freeze in the temperature range which the solar collector may be subject to. The coolant will usually be refrigerant, oil or distilled paraffin.

Closed loop systems are generally more costly than their open loop counter parts and great care must be taken to avoid contamination of the paraffin with refrigerant. The energy captured by the coolant is then transferred to the hot paraffin via a heat exchanger. In a drain back system the coolant may be distilled paraffin. The system works on the principle that there is only paraffin in the collector when the pump is operating.

This has the benefit that the coolant used in the system will not have the chance to cool down during the night when temperature may drop to a level which may cause the coolant to increase in density and thus perhaps cause is not be as free flowing as it should. The only necessary feature on the drain back system is that the solar collector are elevated from the heat exchanger or drain back tank in order for the coolant to flow out of the collector.

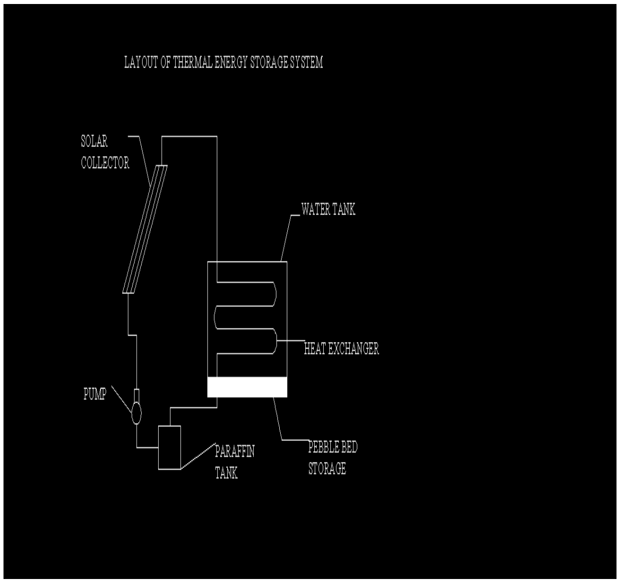
This system again works on the principle that the paraffin is circulated between the collector and the drain back tank when the designated temperature is reached between the solar collector and the hot paraffin.

Centrifugal pump



A centrifugal pump is a rot dynamic pump that uses a rotating impeller to increase the pressure and flow rate of a fluid. Centrifugal pumps are the most common type of pump used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward or axially into a diffuser or volute chamber, from where it exits into the downstream piping system. Centrifugal pumps are typically used for large discharge through smaller heads.
Centrifugal pumps are most often associated with the radial-flow type. However, the term "centrifugal pump" can be used to describe all impeller type rot dynamic pumps including the radial, axial and mixed-flow variations.

Layout diagram of thermal storage



Working principle

The line diagram of thermal energy storage system is shown in the figure. The main parts of the system are solar collector, heat exchanger, pump, paraffin tank.

First the pump lift the liquid paraffin to the solar collector, In solar collector the paraffin absorb the solar heat energy. Then paraffin change vapour stage, thus paraffin passes through the water tank. In water tank heat is transferred to the water and pebble bed storage. The water temperature is maximum for day and night.

Readings

Temperature of water = 60^0c
Time up to 18 hrs

III. CONCLUSION

Through this project I had fabricated and to implemented the Solar Energy to store the Thermal Energy using Paraffin as a phase change material. The main objective through this project was to make utilize of the renewable energy resources as a working material along with paraffin to create and utilize the thermal energy**.**

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