STUDY ON THERMAL ENERGY STORAGE USING PHASE CHANGE MATERIAL

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ABSTRACT

The use of a latent heat storage 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. 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.

Keyword: - *Thermal Energy Storage (TES), Phase Change Material (PCM).*

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1. INTRODUCTION

Now a day's energy demand in commercial, industrial and residential sectors vary on daily, weekly and seasonal basis. These demands can be matched with the help of Thermal Energy Storage (TES) systems that operate synergistically and are carefully matched to each specific application. The use of TES for heating and cooling applications has received much attention. Varies types of new TES techniques have been developed over the past four decades. Well-designed systems can reduce initial and maintenance costs and energy use and demand.

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 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 new technology. 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.

2. THERMAL ENERGY STORAGES

Thermal energy storage can be stored as a change in internal energy of a material as sensible heat, latent heat and thermochemical or combination of these.

2.1 Types of Thermal Energy Storage

a. 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.

b. 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.

- Latent heat storage materials: - Phase change materials (PCM) are ‘‘Latent’’ heat storage materials. The thermal energy transfer occurs when a material changes from solid to liquid, or liquid to solid. This is called a change in state, or ‘‘Phase.’’ Initially, these solid–liquid PCMs perform like conventional storage materials, their temperature rises as they absorb heat. Unlike conventional (sensible) storage materials, PCM absorbs and release heat at a nearly constant temperature. They store 5–14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock. A large number of PCMs are known to melt with a heat of fusion in any required range. However, for their employment as latent heat storage materials these materials must exhibit certain desirable thermodynamic, kinetic and chemical properties.

- Conduction of heat energy: - When end of solid rod is heated the atoms (or molecules) at that end vibrate– the more it is heated the more they vibrate. This vibration is passed on from one atom to the next as they are all linked together in the solid. Heat energy is therefore transmitted down the rod. This is called conduction. In metals there are also a lot of free electrons wandering about and these play a big part in the energy transfer. That is why metals are nearly always better conductors than non-metals.

- Specific heat capacity: - The SPECIFIC HEAT CAPACITY of a substance is the heat needed to raise the temperature of 1kg of the substance by 1K (or by 1˚C).

2.2 Phase Change Materials

A Phase Change Material (PCM) is a substance which, melts and solidifies at certain temperatures and is capable of storing or releasing some amounts of thermal energy. Phase change process involves transforming a material from one phase (solid, liquid, or gas) into another. For example, melting of ice into liquid water or boiling of liquid water into water vapour is classified as a phase change process. During a phase change, molecules rearrange themselves, causing an entropy change of the material system. Thermodynamics necessitates that the material absorb or release thermal energy or heat because of this entropy change, and this heat associated with the unit mass of the material is defined as the latent heat of the material.

The latent heat is released by a material during melting and evaporation; it is absorbed during freezing and condensation phase change processes. The amount of latent heat is significantly larger than the sensible heat gain/loss for temperature changes of ~10 K. The difference could be one to two orders of magnitude. For example, the latent heat of melting ice to water at 32°F (0°C) is 142 Btu/lb. (330 kJ/kg). Compare this with 18 Btu/lb. (42 kJ/kg) of sensible heat, which is required to change the water temperature by 10 K. During a phase change, the temperature of the material remains constant. In short, a phase change process involves a large amount of heat transfer at a constant temperature, and both are attractive features for heating, cooling, and temperature stabilization applications. A material that uses its phase-changing ability for the purpose of heating, cooling, or temperature stabilization is defined as a phase change material (PCM). PCMs have found applications in a wide array of areas such as in thermal energy storage, building energy efficiency, food product cooling, spacecraft thermal systems, solar power plants, microelectronics thermal protection, and waste heat recovery.

- Paraffin wax: - It is a white or colorless soft solid derivable from petroleum, coal or oil shale that consists of a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37 ˚C (99 ˚F). Common applications for paraffin wax include lubrication, electrical insulation and candles.

3. Experimental Study on TES

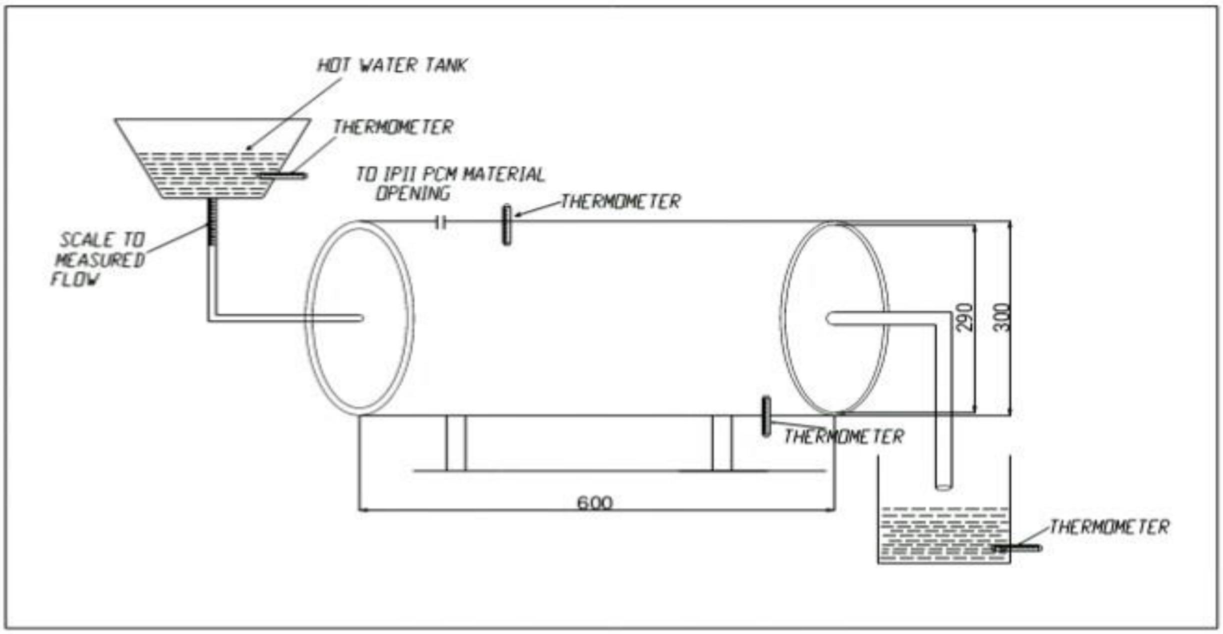

Fig -1: Experimental setup of TES

- Construction: - Hot water tank, copper inner pipe, CPVC (Chlorinated polyvinyl chloride) outer pipe, thermometer, cold water tank.

- Working: - The hot water from the hot water tank is passed through the inner pipe and phase change material is inserted into the annulus which absorbs the heat from the hot water flowing through the inner pipe on the law of thermodynamics. Then it is collected in cold water tank. The PCM absorbs the heat from the hot water, the solid PCM gets converted into liquid form. Then heat absorbed by the PCM is calculated.

- Material Used: -

Sr. No.	Material used	Outside diameter	Inside diameter	Thickness	Safe working pressure	Ultimate pressure	Thermal conductivity	Max allowable tensile stress
1	Copper pipe	30mm	29mm	1mm	4500 kPa	10175 psi	400 W/mK	33 MPa
2	CPVC pipe	300mm	290mm	10mm	-	-	0.04 W/mK	340 MPa

3. Paraffin wax: - Melting temp is 65˚C, density of about 900 kg/m^3, heat of combustion is 42 kJ/g, specific heat capacity of 2.14-2.9 $J\ g^{-1}\ K^{-1}$, heat of fusion of 200-220 $J\ g^{-1}$.

- Note:-

1kPa = 0.145 psi
100kPa = 1 bar

4. CONCLUSIONS

This report is focused on the available thermal energy storage technology with PCMs with different applications. Those technologies is very beneficial for the humans and as well as for the energy conservation. This paper presents the current research in this particular field, with the main focus being on the assessment of the thermal properties of various PCMs. The heat storage applications used as a part of solar water-heating systems, solar air heating systems, solar cooking, solar green house, space heating and cooling application for buildings, waste heat recovery systems. That paper also presents the melt fraction studies of the few identified PCMs used in various applications for storage systems with different heat exchanger container materials.

5. REFERENCES

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