Solar Heat Energy Storage in Phase Change Materials

Shripad Chopade[1], Sagar Kauthalkar[2], Pushpendra Kumar Sharma[3]
[1](Shripad shashikant chopade, scholar student of Mechanical Department, Nri-ist Bhopal, India)
[2](Sagar pradip kauthalkar, scholar student of Mechanical Department, Nri-ist Bhopal, India)
[3](Dr. Pushpendra kumar sharma, Head & Guide of Mechanical Department, Nri-ist Bhopal, India)

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 paper deals with storage of solar thermal energy in materials undergoing phase changes. PCMs, which include salt hydrates, paraffins, non-paraffins, and eutectics of inorganic, are discussed. Heat storage in phase change materials (PCM) has an advantage of compactness and heat supply at constant temperature.

Keywords: *Eutectics, Inorganic compounds, Non-Paraffin's organic solids, Paraffin's organic solids.*

I. INTRODUCTION

Energy storage is a key issue to be addressed to allow intermittent energy sources, typically renewable sources, to match energy supply with demand. There are numerous storage technologies that are capable of storing energy in various forms including kinetic energy, chemical solutions, magnetic fields, or other novel approaches.

PCMs absorb and emit heat while maintaining a nearly constant temperature. Within the human comfort range of 68° to 86°F (20° to 30°C), latent thermal storage materials are very effective. They store 5 to 14 times more heat per unit volume than sensible storage materials such as water, masonry or rock.

Thermal energy can be stored in well-insulated fluids or solids. It can be generally stored as latent heat-by virtue of latent heat of change of phase of medium. In this the temperature of the medium remains more or less constant since it undergoes a phase transformation. Phase change storages with higher energy densities are more attractive for small storage.

Compared to different storage techniques for solar space heating and hot water production applications the operating temperature range for PCM is large, depending on the choice of material .The reason so as to why PCM is a suggested alternative to conventional storage mediums are:

1. Thermal storage capacity per unit mass and unit volume for small temperature differences is high
2. Thermal gradients during charging and discharging is small
3. Simultaneous charging and discharging is possible with appropriate selection of heat exchanger

II. STORAGE IN PHASE CHANGE MATERIALS (PCM)

Phase change materials (PCMs) are "latent" thermal storage materials. They use chemical bonds to store and release heat. The thermal energy transfer occurs when a material changes from a solid to a liquid or from a liquid to a 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 solar heat. Unlike conventional (sensible) storage materials, when PCMs reach the temperature at which they change phase (their melting point) they absorb large amounts of heat without getting hotter. When the ambient temperature in the space around the PCM material drops, the PCM solidifies, releasing its stored latent heat.

Heat storage in phase change has advantage of compactness, since the latent heat of most materials are large compared to their heat capacity over a temperature of order of 20 degrees .It has added advantage of heat supply at constant temperature .The various phase changes that can occur are melting, evaporation, lattice change etc.

The latent heat (enthalpy change) of transformation from one solid phase into another is generally small, but solid-gas and liquid -gas transitions have large heat of transformation, but large changes in volume make the system complex and impractical .The solid liquid transformations involve relatively small volume changes. These are available in a range of heats of fusion and transition temperatures. Some of the mixed fluoride salts exhibit large heats of fusion at melting points high enough for application in heat engines.

The hydrated salts that adsorb heat as they dissolve in their own water of crystallization come in the category of crystalline solid-liquid solution transformation. This process is similar to melting processes and heats of transition are of same order as the heats of fusion but there is no change in volume like in phase change materials. The heat of crystallization is released during the process of crystallization There are a large number of organic and inorganic phase change materials (PCM) that meet the required thermodynamic and kinetic criteria for operation in desired temperature of 0-1400 C but many of them cannot be used due to the problems of chemical stability, toxicity, corrosion, volume change, availability at reasonable cost, etc Solid-solid PCMs absorb and release heat in the same manner as solid-liquid PCMs. These materials do not change into a liquid state under normal conditions. They merely soften or harden. Relatively few of the solid-solid PCMs that have been identified are suitable for thermal storage applications. Liquid-gas PCMs are not yet practical for use as thermal storage. Although they have a high heat of transformation, the increase in volume during the phase change from liquid to gas makes their use impractical. The PCM applications described below are with liquid-solid materials.

III. TYPES OF PCMs

The PCMs fall in three categories:

- Salt hydrates
- Paraffins
- Non paraffin organics

IV. HEAT STORAGE CAPACITIES

Non paraffin organics 125-200 kJ/dm3 Salt hydrate 250 -400 kJ/dm3

V. SALT HYDRATES

Salt hydrates are characterized by X (Y) n .m H2O, where X (Y) n is an inorganic compound. These materials are preferred because of their high latent heat storage density. Salt hydrates such as sodium sulphate decahydrate and calcium chloride hexahydrate have suitable phase change temperatures for use as storage in space heating systems. These have the advantage of larger energy density.

The storage of heat in salt hydrates is in form of heat of fusion, which is latent heat of reaction. If latent heat of reaction is large latent heat storage has the advantage of making smaller systems. At certain temperature these materials release their water of crystallization and the solid remainder dissolves in it or in part.

VI. PARAFFINS

Paraffin's qualify as heat -of- fusion storage materials due to their availability in large temperature range and their reasonably high heat of fusion. Due to cost consideration, only technical grade paraffins may be used as PCMs in latent heat stores. Paraffins like other mineral oil products are complicated mixtures of several organic compounds and contain one major component called alkanes. The desirable characteristics that make them suitable to be used as PCMs are:

4. Congruent melting 5. Good nucleating properties

VII. NON-PARAFFIN ORGANIC SOLIDS

This is the largest category of candidate materials for phase change storage some features of these organic materials are:

6. High heat of fusion
7. Inflammability
8. Low thermal conductivity
9. Varying levels of toxicity
10. Instability at high temperatures
11. Low flash points

VIII. INORGANIC COMPOUNDS AND EUTECTICS

Apart from many inorganic salt hydrates there are many inorganic compounds, which undergo solid liquid phase transformation with high latent heat of fusion at higher temperature. Also apart from the pure compounds, eutectics of organic or inorganic compounds can be used to obtain the desired melting point .It is possible to get a fixed melting or freezing point eutectic mixture of inorganic salts.

IX. CONCLUSION

Solar energy holds the key to future's non-exhaustive energy source. Effective utilization of these resources requires effective storage. Heat storage using 'phase change materials' is a wise alternative.

The main applications for PCMs are when space restrictions limit larger thermal storage units in direct gain or sunspace passive solar systems. Phase change materials may be used in solar domestic hot water heating or passive solar space heating systems. Research is being conducted on methods of incorporating PCMs into other lightweight building materials such as plywood, as well as ceiling and floor tiles. Possible commercial applications include use in paving materials to minimize nighttime icing on bridges and overpasses, while also reducing surface damage from freeze-thaw cycling; outdoor wearing apparel for professionals (e.g., firefighters) or athletes exposed to extreme temperatures; and possible solar evaporator type heat pumps with thermal storage.

X. ACKNOWLEDGMENT

The author wishes to acknowledge the Project Guide Dr. Pushpendra Kumar Sharma, Head of Department Nri-ist Bhopal, India, for their continual guidance.

REFERENCES

[1] Processes and Materials of Manufacture by R.A. LINDBERG
[2] www.pcmag.com/encyclopedia
[3] www.me.sc.edu
[4] H.P Garg, S.C Mullick, *Solar Thermal Energy Storage*, D.Reidal publishing Co.
[5] J.Prakash *Solar Energy Fundamentals*, TATA McGraw Hill
[6] Britannica encyclopedia