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REVIEW OF PHASE CHANGE MATERIALS USEFUL FOR THERMAL STORAGE SYSTEM

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Abstract

Solar energy is one of the powerful sources of energy considering it's clean, pollution free and renewable nature compared with fossil fuels. As solar energy is periodic and irregular in nature it gives limitations for its usage. Even in locations with pleasing solar radiation gives only few hours of high radiant incidence per day.

One way to enhance upon the shortage of solar energy usage is to use thermal energy storage for solar water thermal storage system. Thermal storage system stores energy when collected amount is excess and it discharges energy when collected amount is inadequate. Sensible and latent heat storage materials are used to store thermal energy.

In this paper review of phase change material useful for thermal energy system is studied. Phase change materials, melt and freeze in a narrow temperature range with large heat absorption and release, which is important for many applications in the field of building energy conservation. The latent heat storage of phase change materials is an effective way to reduce energy consumption.

Keywords: - Phase Change Materials (PCM), Solar Water Thermal Storage, Latent Heat Storage.

1. Introduction

A phase-change material 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; thus, PCMs are classified as latent heat storage (LHS) units.

Latent heat thermal energy storage using phase change materials are useful considering their storing and extracting large amount of heat when it undergoes melting and solidification. A phase change material depends on energy absorption or extraction of latent heat during phase transformation.

Due to time-dependent and unpredictable characteristics of sun exposure utilization of solar thermal energy storage tanks with phase change materials can be done to enhance the performance of available solar water thermal systems. Phase change material (PCM) absorbs heat during its phase change cycle from solid to liquid during the daytime solar cycle. The amount of heat that a tank of water can absorb is much higher with the presence of phase change material.

Various PCM materials having thermal conductivity can be used for thermal storage Applications such as solar water heating, building cooling and space heating.

1.1 Need of Thermal energy storage

The thermal energy storage (TES) can be defined as the temporary storage of thermal energy at high or low temperatures. Energy storage can reduce the time or rate mismatch between energy supply and energy demand, and it plays an important role in energy conservation. Energy storage improves performance of energy systems by smoothing supply and increasing reliability. For example, storage would improve the performance of a power generating plant by load leveling. The higher efficiency would lead to energy conservation and improve cost effectiveness.

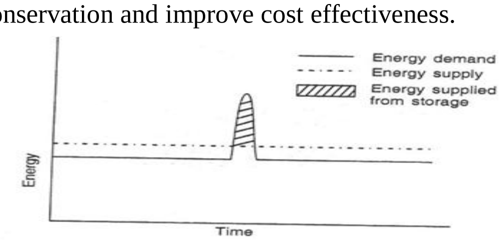


Fig. No. 1 Constant energy supply, sharp pulse (peak load) in energy demand

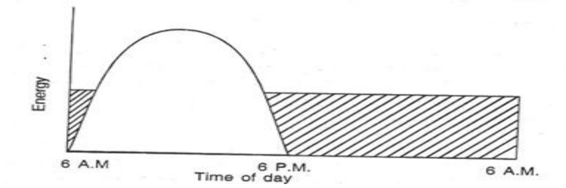


Fig No 2 Constant energy demands, variable energy supply lasting for only half of the diurnal (24 hour cycle)

Storage system store energy for short intervals of time and is relatively small in size is called buffer storage. Figure A and Figure B show short term storage system.

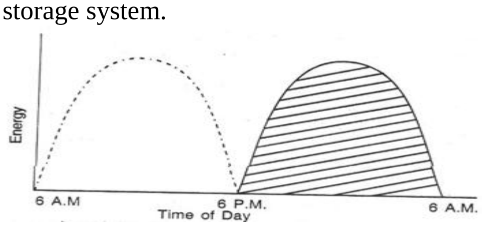
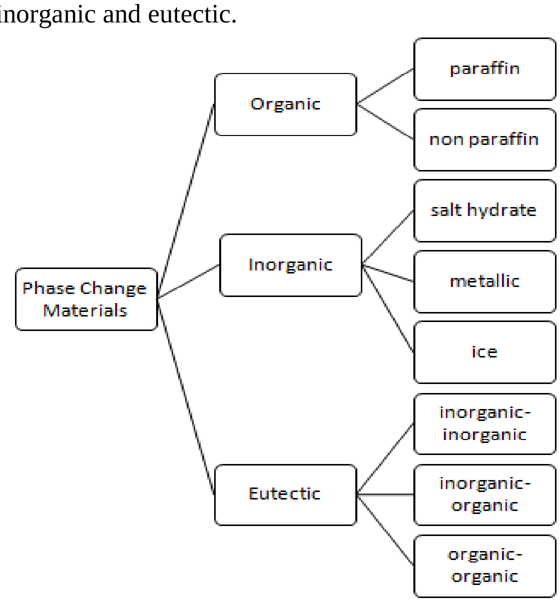


Fig No 3 Variable energy supply and demand with phase difference, the entire demand being met by storage of energy supply

2. Classification of PCMs

There are large number of phase change materials are available in any required temperature range. Phase change materials are mainly classified as organic, inorganic and eutectic.



2.1 Organic phase change materials:

Organic materials are further described as paraffin and non-paraffin. Organic materials include congruent melting means melt and freeze repeatedly without phase segregation and consequent degradation of their latent heat of fusion, self nucleation means they crystallize with little or no super cooling and usually non-corrosiveness.

Paraffins

Paraffin wax consists of a mixture of mostly straight chain alkanes 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.

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

Physical properties of some paraffin's

Non-paraffins

This is the largest category of candidate's materials for phase change storage. These organic materials are further subgroups as fatty acids and other non-paraffin organic. These materials are flammable and should not be exposed to excessively high temperature, flames or oxidizing agents. These materials are flammable and should not be exposed to excessively high temperature, flames or oxidizing agents. Some of the features of these organic materials are as follows: (i) high heat of fusion, (ii) inflammability, (iii) low thermal conductivity, (iv) low flash points, (v) varying level of toxicity, and (vi) instability at high temperatures.

Materials	Melting Point (°c)	Latent Heat (kj/kg)
Formic acid	7.8	247
Glycerin	17.9	198.7
Methyl Palmitate	29	205
Camphenilone	39	205
Docasyl Bromide	40	201
Caprylone	40	259
Phenol	41	120
Acetanilide	118.9	222

Properties of some non-paraffin:

Inorganic phase change material

A number of inorganic compounds and eutectics have been used for high temperature applications. Sodium nitrate, sodium hydroxide, ice are examples.

Salt hydrates

The most attractive properties of salt hydrates are: (i) high latent heat of fusion per unit volume, (ii) relatively high thermal conductivity (almost double of the paraffin's), and (iii) small volume changes on melting. They are not very corrosive, compatible with plastics and only slightly toxic. Many salt hydrates are sufficiently inexpensive for the use in storage. Three types of the behavior of the melted salts can be identified: congruent, incongruent and semi-congruent melting (i) congruent melting occurs when the anhydrous salt is completely soluble in its water of hydration at the melting temperature. (ii) Incongruent melting occurs when the salt is not entirely soluble in its water of hydration at the melting point. (iii) Semi-congruent melting the liquid and solid phases in equilibrium during a phase transition is of different melting composition because of conversion of the hydrate to a lower-hydrated material through loss of water.

Material	Melting point (°C)	Latent heat (kJ/kg)	Group[a]
$K_2HPO_4 \cdot 6H_2O$	14.0	109	II
$FeBr_3 \cdot 6H_2O$	21.0	105	II
$Mn(NO_3)_2 \cdot 6H_2O$	25.5	148	II
$FeBr_3 \cdot 6H_2O$	27.0	105	II
$CaCl_2 \cdot 12H_2O$	29.8	174	I
$LiNO_3 \cdot 2H_2O$	30.0	296	I
$LiNO_3 \cdot 3H_2O$	30	189	I
$Na_2CO_3 \cdot 10H_2O$	32.0	267	II
$Na_2SO_4 \cdot 10H_2O$	32.4	241	II
$KFe(SO_4)_2 \cdot 12H_2O$	33	173	I
$CaBr_2 \cdot 6H_2O$	34	138	II
$LiBr_2 \cdot 2H_2O$	34	124	I
$Zn(NO_3)_2 \cdot 6H_2O$	36.1	134	III
$FeCl_3 \cdot 6H_2O$	37.0	223	I
$Mn(NO_3)_2 \cdot 4H_2O$	37.1	115	II
$Na_2HPO_4 \cdot 12H_2O$	40.0	279	II
$CoSO_4 \cdot 7H_2O$	40.7	170	I
$KF \cdot 2H_2O$	42	162	III
$MgI_2 \cdot 8H_2O$	42	133	III
$CaI_2 \cdot 6H_2O$	42	162	III
$K_2HPO_4 \cdot 7H_2O$	45.0	145	II
$Zn(NO_3)_2 \cdot 4H_2O$	45	110	III
$Mg(NO_3) \cdot 4H_2O$	47.0	142	II
$Ca(NO_3) \cdot 4H_2O$	47.0	153	I
$Fe(NO_3)_3 \cdot 9H_2O$	47	155	I
$Na_2SiO_3 \cdot 4H_2O$	48	168	II
$K_2HPO_4 \cdot 3H_2O$	48	99	II
$Na_2S_2O_3 \cdot 5H_2O$	48.5	210	II
$MgSO_4 \cdot 7H_2O$	48.5	202	II
$Ca(NO_3)_2 \cdot 3H_2O$	51	104	I
$Zn(NO_3)_2 \cdot 2H_2O$	55	68	III
$FeCl_3 \cdot 2H_2O$	56	90	I
$Ni(NO_3)_2 \cdot 6H_2O$	57.0	169	II
$MnCl_2 \cdot 4H_2O$	58.0	151	II
$MgCl_2 \cdot 4H_2O$	58.0	178	II
$CH_3COONa \cdot 3H_2O$	58.0	265	II
$Fe(NO_3)_2 \cdot 6H_2O$	60.5	126	–
$NaAl(SO_4)_2 \cdot 10H_2O$	61.0	181	I
$NaOH \cdot H_2O$	64.3	273	I
$Na_3PO_4 \cdot 12H_2O$	65.0	190	–
$LiCH_3COO \cdot 2H_2O$	70	150	II
$Al(NO_3)_2 \cdot 9H_2O$	72	155	I
$Ba(OH)_2 \cdot 8H_2O$	78	265	II
$Mg(NO_3)_2 \cdot 6H_2O$	89.9	167	II
$KAl(SO_4)_2 \cdot 12H_2O$	91	184	II
$MgCl_2 \cdot 6H_2O$	117	167	I

Melting point and latent heat of fusion of salt Hydrate:

Metallic

They have high thermal conductivities, so fillers with added weight penalties are not required. The use of metallics poses a number of unusual engineering problems. A major difference between the metallics and other PCMs is their high thermal conductivity. A list of some selected metallics is given in. Some of the features of these materials are as follows: (i) low heat of fusion per unit weight (ii) high heat of fusion per unit volume, (iii) high thermal conductivity, (iv) low specific heat and (v) relatively low vapor pressure.

Material	Melting point (°C)	Latent heat (kJ/kg)
Gallium–gallium antimony eutectic	29.8	–
Gallium	30.0	80.3
Cerrolow eutectic	58	90.9
Bi–Cd–In eutectic	61	25
Cerrobend eutectic	70	32.6
Bi–Pb–In eutectic	70	29
Bi–In eutectic	72	25
Bi–Pb–tin eutectic	96	–
Bi–Pb eutectic	125	–

Melting point and latent heat of fusion of metallic

2.2.4 Eutectics

A eutectic is a minimum-melting composition of two or more components, each of which melts and freeze congruently forming a mixture of the component crystals during crystallization. Eutectic nearly always melts and freezes without segregation since they freeze to an intimate mixture of crystals, leaving little opportunity for the components to separate. On melting both components liquefy simultaneously, again with separation unlikely. Some segregation PCM compositions have sometimes been incorrectly called eutectics, since they are minimum melting.

3. Phase Change materials properties

Thermal properties:-
(a) Suitable phase-transition temperature.
(b) High latent heat of transition.
(c) Good heat transfer.
(d) Lower change of volume during phase change.
(e) Melting point in the desired operating temperature range.
(f) High thermal conductivity both in liquid as well as in solid phases that gives additional sensible thermal energy storage and also avoid sub cooling.

A) Physical properties:-
(a) Favorable phase equilibrium.
(b) High density.
(c) Small volume change.
(d) Low vapour pressure.

B) Kinetic properties:-
(a) No super cooling.
(b) Sufficient crystallization rate.

C) Chemical properties:-
(a) Long-term chemical stability.
(b) Compatibility with materials of construction.
(c) No toxicity.
(d) No fire hazard.
(e) Non flammable.
(f) No chemical decomposition.

D) Economics:
(a) Abundant.
(b) Available
(c) Cost effective

The performance of Phase change material is measured by using various parameters such as

1. The stability of PCM.
2. Thermal Conductivity of PCM.
3. Its heat storage capacity.
4. By its melting point.
5. By its fusing point.
6. Payback period.
7. As per safety to operation.
8. Toxicity.

4. Conclusion:

Among three types of phase change materials as organic, inorganic and eutectics; inorganic materials are having attractive properties compared with organic ones. Salt hydrates shows high melting enthalpy as well as high density compared to organic phase change materials. Inorganic materials are less expensive and non flammable comparison to organic compounds. R & D efforts are required to discover more reliable way of using phase change materials. Phase change materials can be used as a part of solar air heating, solar water-heating, solar air heating systems, solar cooking, solar green house, space heating and cooling application for buildings, off-peak electricity storage systems and waste heat recovery systems

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