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Phase Change Material and its Selection Criteria-An Overview

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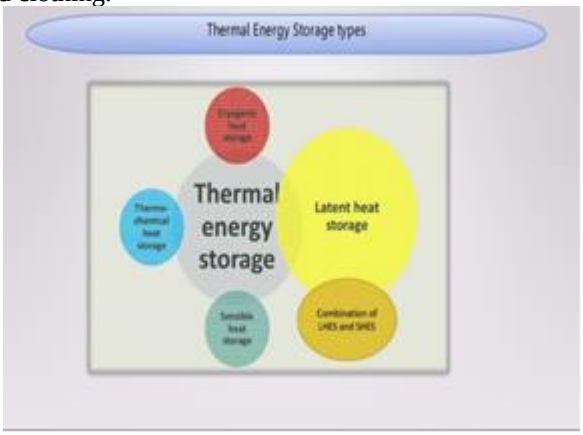
***Abstract* – In this review paper we are going to study about the latent heat storages (phase change materials) their use in different applications and also about their properties, types and selection criteria. we will also be studying how to calculate thickness according to load and different calculations required in cold storage applications.**

Key Words: Phase change material,

1. INTRODUCTION

A phase change material (PCM) is a substance which releases/absorbs sufficient energy at phase transition to provide useful heat/cooling. Generally, the transition will be from one of the first two fundamental states of matter - solid and liquid to the other. The energy released/absorbed by phase transition from solid to liquid, or vice-versa, the heat of fusion is generally much higher than the sensible heat. By melting and solidifying at the phase change temperature (PCT), a PCM is capable of storing and releasing large amounts of energy compared to sensible heat storage. Heat is absorbed or released when the material changes from solid to liquid and vice versa or when the internal structure of the material changes; PCMs are accordingly referred to as latent heat storage (LHS) materials. PCMs are used in many different commercial applications where energy storage and/or stable temperatures are required, including, among others, heating pads, cooling for telephone switching boxes, and clothing.



2. LITERATURE REVIEW

2.1 Performance Improvement of a Domestic Refrigerator byusing PCM (Phase Change Material)

The paper investigates the performance improvement provided by a phase change material associated with the evaporator in a domestic refrigerator. The heat release and storage rate of a refrigerator depends upon the characteristics of refrigerant and its properties.

The usage of PCM as TS will help to improve the COP (Coefficient of performance) of new refrigeration cycle by introducing a new sub cooling routine. The analysis of the experiment exemplifies the improvement of the system coefficient of performance considerably. Using water as PCM and for a certain thermal load it is found that the coefficient of performance of the conventional refrigerator increased by 55-60%. This improvement by sub cooling can be done for single evaporator refrigeration system. Because of prolonging of the compressor off time by using the latent heat of energy of the PCM capsulated ice, used as the thermal energy storage material, has been investigated numerically. We can have better food quality due to lower hysteresis cycles of on/off for a given period of operation.

2.2 Performance Improvement and Energy Consumption Reduction In Refrigeration Systems Using Phase Change Material (PCM)

This paper presents a review of various research investigations on the application of phase change material (PCM) in refrigeration systems. Application of PCMs mostly in vapor compression refrigeration systems refrigeration systems have illustrated significant effects on the performance of the system, compressor on-off cycle and electricity consumption reduction. Since PCM must be chemically and thermally stable over a large number of freezing/melting cycles to be applicable for thermal energy storage in refrigerators, PCM selection for refrigeration systems is discussed as an important issue. Moreover, influences of some parameters such as PCM thickness and phase change temperature of PCM on the performance of refrigeration systems are reviewed. The advantages and drawbacks of using PCM in the evaporator, condenser, compartment section and compressor are evaluated. Using PCM at the evaporator section minimizes the fluctuation of compartment temperature and provides stable conditions against thermal load variations. Since incorporation of PCM at the evaporator increases the compressor running time initially and raises the condensation temperature, several investigations were performed to incorporate PCM at the condenser section. With an alarming rate of rise in the use of refrigerators, along with their total electrical consumption in today's world, the application of PCM on refrigerators looks like a viable measure to increase the efficiency of refrigerators and reduce the energy consumption.

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2.3 Characteristics and Thickness Effect of Phase Change Material And Frost on Heat Transfer and Thermal Performance of Conventional Refrigerator: Theoretical and Experimental Investigation

In order to design more energy-efficient refrigeration systems through means that have no impact on the environment, the use of phase change materials (PCMs) coupled to the refrigeration systems could be one of the most economically attractive solutions. Among the many possible arrangements of the PCM within a refrigerator, PCM is often on the surface of the evaporator, the location where frost forms. However, beyond a certain thickness, frost
would cause an excessive increase in the refrigerator air temperature and a reduction in the energy performance of the refrigerator. The aim of the present study is to clarify the nature and characteristics of frost compared to water as phase change material (PCM), along with the
mechanisms with which they affect energy performance and heat transfer within the
refrigerator. This is based on a theoretical and experimental investigations conducted on a conventional refrigerator equipped with a flat plate evaporator.

2.4 The Use of Phase Change Materials in Domestic Refrigerator Applications

In this paper different models of refrigeration system were explained their functioning without using phase change material were explained the models were studied with and without phase change materials , the effect of phase change materials was studied and graphs were plot of melting time vs melting point of phase change materials and freezing time versus freezing point of phase change material ,the melting time and freezing time were calculated in minutes while the melting and freezing point in degree centigrade, also the graph were plotted for two 2 different pcm thickness of about 2mm, 5mm.
The experimentation was carried out through a experimental setup and the result obtained from experimentation was compared with the theoretical result achieved through the CFD analysis. The results concluded that larger thickness of phase change material give better result as compared to smaller thickness.

2.5 Phase Change Materials: Characteristics and Encapsulation

In this paper they have done a detailed study about thermal energy storages, explained about what are phase change materials, discussed its types in details which are organic, inorganic, eutectic. They also studied the problems faced by usage of phase change material and how it can be overcome, the paper also studied the encapsulation of phase change material and also studied about the applications of phase change materials.

3. CLASSIFICATION AND TYPE OF PHASE CHANGE MATERIAL

3.1 Organic PCM

1. Paraffins
2. Non paraffins

3.2 Inorganic PCM

1. Salt hydrates
2. Metallic

3.3 Eutectic PCM

1. Organic-organic
2. Non organic-non organic
3. Organic-non organic

4. SELECTION CRITERTIA OF PHASE CHANGE MATERIAL

4.1 Based on Properties of Phase Change Material

4.1.1 Based on Thermal Properties:

a) Suitable melting point for particular operation.
b) High latent heat of fusion per unit volume.
c) High thermal conductivity of solid and liquid phases for better heat transfer.
d) Higher specific heat for additional sensible heat storage.

4.1.2 Based on Physical Properties

a) High density for smaller container volume.
b) Small volume change during
phase transition.
c) Low vapor pressure to reduce
the containment problem.

4.1.3 Based on Kinetic Properties

a) Little or no super cooling during freezing
b) High rates of nucleation and growth.
c) Effective heat transfer.

4.1.4 Based on Chemical Properties

No degradation after no. of freeze/melt cycle.

4.2 Based on PCM Thickness:

4.2.1 Effect of PCM Thickness on The PCM Melting and Freezing Time:

Four PCM thicknesses were considered by the model. The PCM total storage capacity varied between 138 kJ for a 2 mm slab and 345 kJ for a 5 mm slab. The heat load and cooling capacity used to predict the PCM melting and freezing times with different thicknesses correspond to an ambient temperature of 25°C and the model results are shown in in figures below,

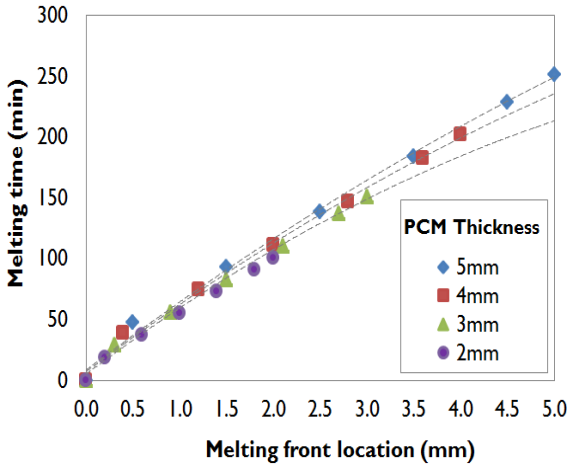

FIG1. Effect of Pcm Thickness on Melting Time

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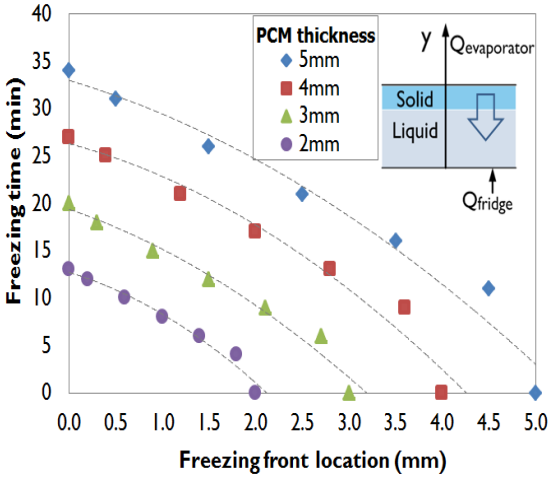


FIG2. EFFECT OF PCM THICKNESS ON FREEZING TIME

4.3 Application Of P.C.M

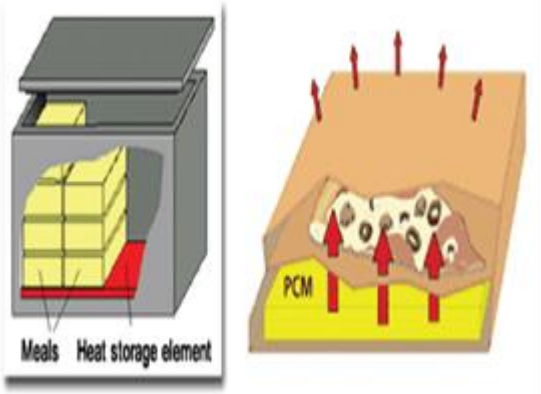
Here the use of PCM in different applications is presented, differentiating those ones that are already in the market from those ones that have been studied by researchers.

1. Thermal Storage Application:

a. General containers for temperature sensitive food: One of the most known applications of PCM is that of transport of temperature sensitive food in containers. These containers must be kept in the refrigerator/freezer before use in order to solidify the PCM in it. An example of such a device is the container commercialized by SOFIGRAM with PCM melting points of 0 ºC, -15 ºC and -20ºC. Some companies only commercialize PCM pads for use in any container, such as TCP RELIABLE, Inc., PCM Thermal Solutions or PCM products.

b. Beverages: One application that has been commercialized is the so called "isothermal water bottle", specially developed for cycling. It is a double wall bottle, with a PCM as active part. This concept could be used for many other products, such as isothermal maintenance of fresh drinks like wine, champagne, soft drink, etc.

c. Catering products: In many catering applications, cooked meals or frozen products are produced in one point and have to be transported to another destination. PCM containers could also be used to avoid breaking the cold chain during transportation of precooked meals, smoked salmon, milk products, ice-creams and many others.



d. Medical applications: In the medical sector, one of the main applications is the transport of blood and organs. Containers used for these purposes work similar to those explained before. Other medical applications can be cold or hot pads to treat local pain in the body.

2.Air Conditioning

PCM Used- Magnesium Nitrate Hexahydrate

Until very recently, pcm were not reliable enough to be used in air condition. We have developed pcm with almost infinite life and good performance in the human comfort range of 18C (64F) to 29C (84F) and further for electronic comfort at higher temperature.

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3.Telecom Shelters

PCM Used - N-eicosane

Telecom shelters are insulated, air-conditioned enclosures that house the heart of mobile communication, the Base Transceiver Station (BTS).BTS, and also the battery, is very temperature sensitive and its surroundings should always be maintained below 35 deg C. In under-developed countries, there are frequent power cuts and singlephasing, forcing cellular service providers to install Diesel Generators to support the air conditioner in case of power cuts or single phasing. Phase Change Material PCM installed in Telecom Shelter will absorb heat in case of unavailability of power, minimizing/eliminating use of DG Sets. PCM will get re-charged when power source is available. Thus, PCM store energy using a cheap source of power and release it when that cheap source of power is not available, thus saving on DieselCost. Telecom Shelters PCM

4.Transportation-

Transportation of perishable foods, temperature sensitivepharmaceuticals, Sundry electronics (like ignition transformers) and chemicals (explosives) require refrigerated trucks. Such refrigerated trucks are prohibitively expensive to operate as they use Diesel as a source of energy. Cost of diesel-generated energy is 6 times higher as compared to conventional electricity cost. Thus, Phase Change Material store energy using a cheap source of power and release it when that cheap source of power is not available.Phase Change Material - General Products like Green House &Electronic cooling.

5.Automobiles

PCM Used - alkyl hydrocarbons, exfoliated graphite PCM is already used today in a latent heat battery offered by BMW as optional equipment in its 5 series. The principle is quite simple; the storage material is connected to the radiator and stores excess heat when the motor runs at operating temperature. This heat is then available at the next cold start to heat up the motor quickly (better gas mileage) and for the interior (driving comfort). Due to the latent heat battery's excellent insulation, it can maintain the energy for 2 days at an outside temperature of – 20°C. As an extension to this application, PCM can also be used in tail-pipes (exhaust) of vehicles. This will maintain the catalytic converter at its design temperature, reducing excessive Hydro-carbon emissions during vehicle start up.

6.House Heating, Warm Water

PCM Used - Erythritol, Adipic Acid, HDPE

Solar energy is not available at all times, and therefore solar installations require an intermediary storage of the energy for heating or warm water. PCM based system will offer the following benefits over a conventional system: Low volume in comparison to water storage systems and a higher efficiency due to a lower temperature difference between loading and discharging of the energy. Latent heat storage can also be implemented in conventional heating systems. Phase Change Material based solar water heater will also give a better controlled water temperature. Natural Cooling Phase Change Material – PCM.

7.Electronics

PCM Used - N-eicosane

Electronic circuitry is extremely sensitive to over-heating, negatively influencing both lifetime and reliability of the parts.Today, metal fins are used for heat sinking improving their cooling capacity with additional fans. The sinking of heat peaks using PCM is absolutely reliable since no motor or temperature measurements are required. The PCM regenerates itself between peaks by emitting the heat with cooling fins.The advantage is a smaller cooling system with a very high reliability.

8.Green House

PCM Used - CaCL2.6H2O

It is important to maintain temperatures in a small range to enable plants cultivated in a greenhouse to flourish. However,due to large temperature swings in daytime and night time temperatures, most green houses need air-conditioning and/or heating. Phase Change Material installed in the floor of such green houses will eliminate or reduce the dependence on air-conditioning/heating.

9.Solar Water Heating System

PCM Used - Stearic Acid

Solar water heaters are gaining tremendous popularity nowadays as they are relatively inexpensive and easy to maintain. A built-in storage-type water heater contains 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 as it changes its phases from liquid to solid.

10.Cooling Helmets

PCM Used - Climsel C28

The PCM helmet cooling system is simple and has the potential to be implemented as a practical solution to provide a Comfortable experience to motorcycle riders and sportspersons. In 2006, Tan and Fok designed a helmet cooling system using PCM to absorb and store the users' body heat to achieve comfort cooling . The PCM is packed into a pouch and placed such that it is in contact with the users. The heat from the users' bodies is conducted to the PCM so that the PCM temperature is maintained just below that of the users' body temperature. This keeps the user cool and alert. The cooling unit is able to provide comfort cooling up to 2.

5. A CASE STUDY: PERFORMANCE IMPROVEMENT OF A DOMESTIC REFRIGERATOR BY USING PCM (PHASE CHANGE MATERIAL)

Experiments were carried out under certain thermal loads with water as PCM. Here the effect PCM in certain quantities in this case 5 litres at certain thermal loads on the performance parameter of house hold refrigerator. The number of compressors on-off cycle within a certain period of time for different PCMs and without PCM can be pointed up. Use of water as PCM imposes a great impact on COP improvement at certain thermal loads. Using water as PCM and certain thermal load it is found that the 55-

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60%COP improvement has been achieved by the PCM in respect without PCM in conventional refrigerator.

During the compressor running the refrigerant takes the chamber heat by free convection in case of without PCM, which is slower heat transfer process in respect to conduction process. But PCM most of the

heat in the cabinet is stored in the PCM during compressor running time. Since the conduction heat transfer process is faster than the free convection processes the cooling coil temperature does not require dropping very low to maintain desired cabinet temperature. As result the evaporator work sat high temperature and pressure with PCM. Moreover, due to high operating pressure and temperature of the evaporator the density of the refrigerant vapor increases, as a result the heat extracted from the evaporator by the fixed volumetric rate compressor is higher than without PCM.

The experiments were carried on for calculating the C.O.P of the refrigeration system with and without pcm the results of which are given below table:

COP Found in Each Test Run Without and With Phase Change Material (PCM)

Number of observations	C.O.P found in vapor compression refrigeration system without PCM	C.O.P found in vapor compression refrigeration system with PCM
1	6.12	9.85
2	5.55	9.42
3	6.12	9.45
4	5.5	9.04
5	5.13	9
6	6.78	9
7	5.1	9
8	5.11	8.91
9	5.02	8.82
10	5.02	8.91

So, from the above table we conclude the case study by the following points:

1.In case of without PCM and with PCM the COP

is higher at low thermal load while it decreases with it decreases with the increase of thermal load.

2. Use of PCM decreases the fluctuation of the cabinet temperature. At higher load this effect is not so significant.

6. CONCLUSION:

In this review paper we have identified various phase change materials and summarized their physical, thermal and chemical properties. We have determined a criterion for the selection of PCM's based on the mechanical and thermal requirement we have identified various applications of phase change materials which have assisted in bringing down the consumption of energy worldwide the energy storage systems like PCM exhilarate energy system performance and reliability. Also, in this review we have seen effect of PCM thickness on the PCM melting and freezing time. we studied different researches relating to this topic and we also completed a study on following research paper: Performance Improvement of a Domestic Refrigerator by using PCM (Phase Change Material).

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