PHASE CHANGE MATERIALS (PCM).

IS IT:

- [ ] *Product*
- [X] *Technology*
- [ ] *Equipment*

APPLICABLE FOR:

- [ ] *Restoration*
- [X] *Rehabilitation*
- [X] *New Construction*

APPLICABLE ON:

- [ ] *1. Foundations and underground structures*
- [ ] *2. Vertical structures*
- [ ] *3. Horizontal structures and vertical connections*
- [X] *4. Roof and terraces*
- [X] *5. Façade and building envelope*
- [ ] *6. Finishes and completion elements*
- [X] *7. Integrated services*
- [ ] *8. General strategies for building recovery*

Related companies: *No companies; university research; structural study.*

DESCRIPTION

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 phase transition may also be between non-classical states of matter, such as the conformity of crystals, where the material goes from conforming to one crystalline structure to conforming to another, which may be a higher or lower energy state.

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. Ice, for example, requires 333.55 J/g to melt, but then water will rise one degree further with the addition of just 4.18 J/g. Water/ice is therefore a very useful phase change material and has been used to store winter cold to cool buildings in summer since at least the time of the Achaemenid Empire.

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.

There are two principal classes of phase change material: organic (carbon-containing) materials derived either from petroleum, from plants or from animals; and salt hydrates, which generally either use natural salts from the sea or from mineral deposits or are by-products of other processes. A third class is solid to solid phase change.

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.

By far the biggest potential market is for building heating and cooling. PCMs are currently attracting a lot of attention for this application due to the progressive reduction in the cost of renewable electricity, coupled with limited hours of availability, resulting in a mismatch between peak demand and availability of supply. In North America, China, Japan, Australia, Southern Europe and other developed countries with hot summers, peak supply is at midday while peak demand is from around 17:00 to 20:00. This creates a lot of demand for storage media.

Solid-liquid phase change materials are usually encapsulated for installation in the end application, to be contained in the liquid state. In some applications, especially when incorporation to textiles is required, phase change materials are micro-encapsulated. Micro-encapsulation allows the material to remain solid, in the form of small bubbles, when the PCM core has melted.

WHY TO USE

Capturing and storing energy is difficult. Phase change materials (PCMs) are ideal for use in any application where a storage and release of thermal energy is desired. PCMs act like a battery for heat energy because they absorb heat energy as they melt and can be “recharged” by cooling them until they crystallise and give the stored energy back to the environment. They can store and release heat energy thousands of times without change in thermal properties.

- High heat storage capacities.
- Consistent, repeatable performance over thousands of thermal cycles.
- Simple and safe handling.
- Also based on renewable raw materials, nontoxic and biodegradable.
- Constant Temperature maintenance during release and absorption of Energy.
- To maintain desired temperature without the need for an external source of energy at the time of operation.
- To shift peak power loads to off- peak power hours.
- To provide as a back-up.

HOW TO USE AND APPLY

Applications include, but are not limited to:

- Thermal energy storage
- Solar cooking
- Cold Energy Battery
- Conditioning of buildings, such as 'ice-storage'

- Cooling of heat and electrical engines
- Cooling: food, beverages, coffee, wine, milk products, green houses
- Delaying ice and frost formation on surfaces[127]
- Medical applications: transportation of blood, operating tables, hot-cold therapies, treatment of birth asphyxia[125]
- Human body cooling under bulky clothing or costumes.
- Waste heat recovery
- Off-peak power utilization: Heating hot water and Cooling
- Heat pump systems
- Passive storage in bioclimatic building/architecture (HDPE, paraffin)
- Smoothing exothermic temperature peaks in chemical reactions
- Solar power plants
- Spacecraft thermal systems
- Thermal comfort in vehicles
- Thermal protection of electronic devices
- Thermal protection of food: transport, hotel trade, ice-cream, etc.
- Textiles used in clothing
- Computer cooling
- Turbine Inlet Chilling with thermal energy storage
- Telecom shelters in tropical regions. They protect the high-value equipment in the shelter by keeping the indoor air temperature below the maximum permissible by absorbing heat generated by power-hungry equipment such as a Base Station Subsystem. In case of a power failure to conventional cooling systems, PCMs minimize use of diesel generators, and this can translate into enormous savings across thousands of telecom sites in tropics.

TECHNICAL CHARACTERISTICS

Characteristics and classification

Latent heat storage can be achieved through changes in the State of matter from liquid→solid, solid→liquid, solid→gas and liquid→gas. However, only solid→liquid and liquid→solid phase changes are practical for PCMs. Although liquid–gas transitions have a higher heat of transformation than solid–liquid transitions, liquid→gas phase changes are impractical for thermal storage because large volumes or high pressures are required to store the materials in their gas phase. Solid–solid phase changes are typically very slow and have a relatively low heat of transformation.

Initially, solid–liquid PCMs behave like sensible heat storage (SHS) materials; their temperature rises as they absorb heat. Unlike conventional SHS materials, however, when PCMs reach their phase change temperature (their melting point) they absorb large amounts of heat at an almost constant temperature until all the material is melted. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. A large number of PCMs are available in any required temperature range from −5 up to 190 °C. Within the human comfort range between 20 and 30 °C, some PCMs are very effective, storing over 200 kJ/kg of latent heat, as against a specific heat capacity of around one kJ/(kg*°C) for masonry. The storage density can therefore be 20 times greater than masonry per kg if a temperature swing of 10 °C is allowed. However, since the mass of the masonry is far higher than that of PCM this specific (per mass) heat capacity is somewhat offset. A masonry wall might have a mass of 200 kg/m2, so to double the heat capacity one would require an additional 10 kg/m2 of PCM.

Organic PCMs

Hydrocarbons, primarily paraffins (CnH2n+2) and lipids but also sugar alcohols.

Advantages:

- Freeze without much supercooling
- Ability to melt congruently
- Self nucleating properties
- Compatibility with conventional material of construction
- No segregation

- Chemically stable
- Safe and non-reactive

Disadvantages:

- Low thermal conductivity in their solid state. High heat transfer rates are required during the freezing cycle. Nano composites were found to yield an effective thermal conductivity increase up to 216%.
- Volumetric latent heat storage capacity can be low
- Flammable. This can be partially alleviated by specialised containment.

Inorganic

Salt hydrates (MxNyH2O)

Advantages:

- High volumetric latent heat storage capacity
- Availability and low cost
- Sharp melting point
- High thermal conductivity
- High heat of fusion
- Non-flammable

Disadvantages:

- Difficult to prevent incongruous melting and phase separation upon cycling, which can cause a significant loss in latent heat enthalpy.
- Corrosive to many other materials, such as metals. This can be overcome by encapsulation in small quantities in non-reactive plastic.
- Change of volume is very high in some mixtures
- Super cooling can be a problem in solid–liquid transition, necessitating the use of nucleating agents which may become inoperative after repeated cycling

Hygroscopic materials

Many natural building materials are hygroscopic, that is they can absorb (water condenses) and release water (water evaporates). The process is thus:

- Condensation (gas to liquid) $\Delta H<0$; enthalpy decreases (exothermic process) gives off heat.
- Vaporization (liquid to gas) $\Delta H>0$; enthalpy increases (endothermic process) absorbs heat (or cools).

Whilst this process liberates a small quantity of energy, a large surface area allows significant (1–2 °C) heating or cooling in buildings. The corresponding materials are wool insulation and earth/clay render finishes.

Solid-solid PCMs

A specialised group of PCMs that undergo a solid/solid phase transition with the associated absorption and release of large amounts of heat. These materials change their crystalline structure from one lattice configuration to another at a fixed and well-defined temperature, and the transformation can involve latent heats comparable to the most effective solid/liquid PCMs. Such materials are useful because, unlike solid/liquid PCMs, they do not require nucleation to prevent supercooling. Additionally, because it is a solid/solid phase change, there is no visible change in the appearance of the PCM, and there are no problems associated with handling liquids, e.g. containment, potential leakage, etc. Currently the temperature range of solid-solid PCM solutions spans from -50 °C (-58 °F) up to +175 °C (347 °F).

RECOMMENDATIONS AND OTHER INFORMATION

Selection criteria

The phase change material should possess the following thermodynamic properties:

- Melting temperature in the desired operating temperature range
- High latent heat of fusion per unit volume
- High specific heat, high density, and high thermal conductivity
- Small volume changes on phase transformation and small vapor pressure at operating temperatures to reduce the containment problem
- Congruent melting
- Kinetic properties

- High nucleation rate to avoid supercooling of the liquid phase
- High rate of crystal growth, so that the system can meet demands of heat recovery from the storage system
- Chemical properties
- Chemical stability
- Complete reversible freeze/melt cycle
- No degradation after a large number of freeze/melt cycle
- Non-corrosiveness, non-toxic, non-flammable and non-explosive materials
- Economic properties
- Low cost
- Availability

Fire and safety issues

Some phase change materials are suspended in water, and are relatively nontoxic. Others are hydrocarbons or other flammable materials, or are toxic. As such, PCMs must be selected and applied very carefully, in accordance with fire and building codes and sound engineering practices. Because of the increased fire risk, flame spread, smoke, potential for explosion when held in containers, and liability, it may be wise not to use flammable PCMs within residential or other regularly occupied buildings. Phase change materials are also being used in thermal regulation of electronics.

EXAMPLES

Material in experimentation/research phase, no examples found at the moment of the realization of this sheet.

REFERENCES / SOURCES AND LITERATURE

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WEBSITE OF THE COMPANY

https://www.axiotherm.de/en/

https://www.croda.com/en-gb

https://phasechange.com/

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IMAGES AND CAPTIONS

APPLICATIONS

Fig.1: Freezers and Coolers: Major freezer and cooler manufacturers have started using phase change materials in their freezer to avoid the spoilage of products during power cut-offs. *©PLUSS.CO.IN*

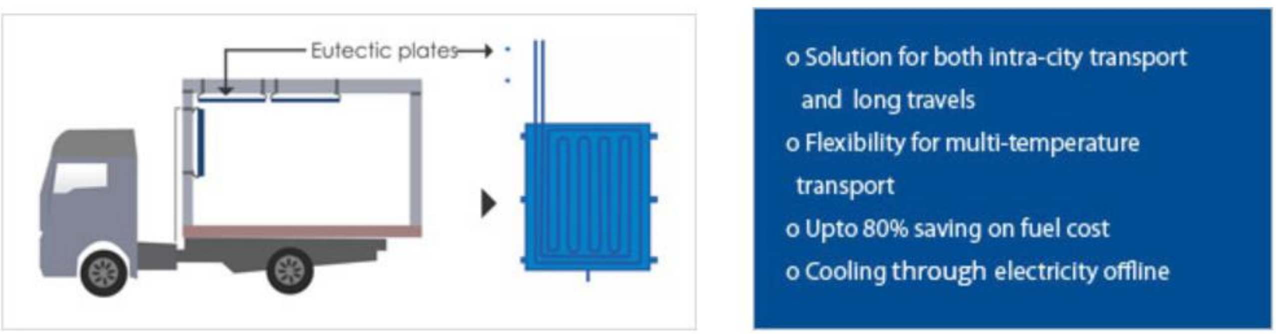


Fig.2: Cold Chain Logistics: The PCM based eutectic plates offer solutions to existing challenges in the cold supply chain issues such as power outages, poor infrastructure, high fuel costs and critical last mile etc. When compared with traditional reefer trucks, this technology offers up to 80% savings in operating cost by virtue of the reduction in diesel consumption. In addition PCM enables multi-temperature transport improving the payload factor thereby improving feasibility of part load transportation. *©PLUSS.CO.IN*

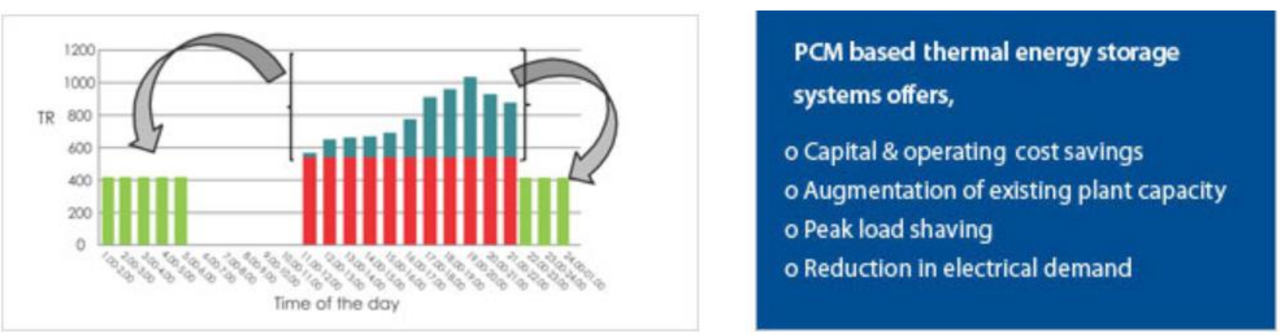
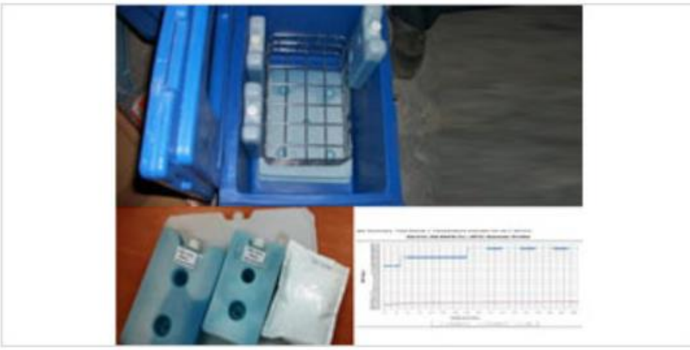


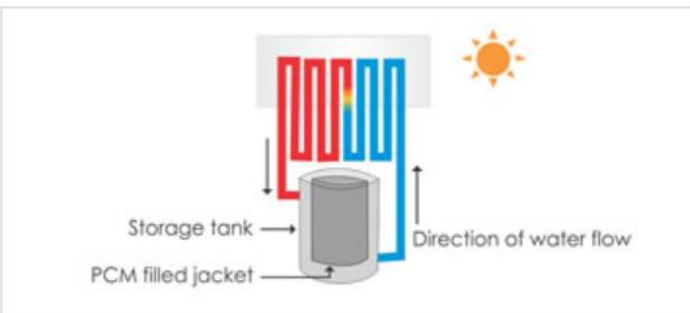
Fig.3: While trying to reduce the usage of power consumption an innovative strategy being adopted globally is to manage the energy effectively by demand side management. The concept of demand side management is to use Phase Change Materials having a high thermal energy storage capacity which uses power during off peak hours to store the energy and release it during peak hours. This strategy allows almost 50% of the HVAC load to be shifted to the night time/off peak hours, which translates to an overall reduction of more than 25% in the total electrical load of a building. *©PLUSS.CO.IN*



PCM based passive cooling offers,

- Temperature backup up to 96 hours
- Solution for both Hot and Cold products
- Re-usability
- Safety with non-hazardous materials
- Precise temperature control with customized PCMs

Fig.4: Pharmaceutical Shipping: Biopharmaceuticals and vaccines contribute to a majority of shipments of temperature-sensitive pharmaceuticals, which are typically high in monetary value and have low product volume. With the surge in mail order shipments, increasing scrutiny by regulatory agencies and the desire to lower costs, the need to develop an effective and reliable cold chain management protocol has become a necessity and is of utmost importance. PCMs provide an innovative, efficient and cost effective way of transporting temperature-sensitive pharmaceutical products and it can bridge the gap between the regulatory policies & guidelines and the need of the consumer concerning product safety. *©PLUSS.CO.IN*



PCM based Solar application helps increase solar energy utilization

Fig.5: Solar Energy Storage: An effective solar thermal storage system must form an integral part of a solar heating system for without this maximum utilization of solar energy is not possible. Thermal storage can also address the problem in trying to match supply to demand where maximum solar availability occurs during the day, but maximum demand occurs at times when there is a little, if any, solar availability. *©PLUSS.CO.IN*

PCM integrated in the building materials offers,

- Dynamic insulation
- A flat temperature profile in the room temperature
- Increase in efficiency of the HVAC system

Fig.6: Building Materials: PCMs in buildings enable storage of free natural energy for heating or cooling purposes reducing the energy consumption by over 30%. *©PLUSS.CO.IN*

Fig.7: Retail Products: There are numerous applications among home appliances and consumer durable products which can be enhanced with the integration of Phase Change Materials. The possibility is endless. *©PLUSS.CO.IN*