"Constantin Brâncuşi" University of Târgu Jiu ENGINEERING FACULTY
SCIENTIFIC CONFERENCE – 13 th edition – with international participation
November 07-08, 2008 – Târgu Jiu

ADVANCES IN HEAT STORAGE TECHNOLOGIES. PHASE CHANGE MATERIALS - AN OVERVIEW

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Abstract. Phase change materials are substances with a high value of latent heat which is capable of storing large amounts of heat by melting; the heat stored during the melting process is released through solidification. Phase Change Materials (PCMs) store energy by changing phase from solid to liquid (melting) and releasing heat by changing phase from liquid to solid (solidification). Phase change materials provide a large heat capacity over a limited temperature range.

1. Introduction

At the 1992 conference on climate change, the United Nations Inter-governmental panel concluded that a 60% reduction in the use of fossil fuel would have to be made in order to freeze the level of CO_2 emissions by the year 2005 . This will have a major affect on the way in which fuel is currently being used, forcing a higher reliance and use of alternative and renewable energy sources. This has tremendous implications in the residential building sector as currently they account for over half of the fuel consumed, with 60% of emissions being attributed to lighting and heating these buildings.

The amount of energy in terms of sunlight reaching the earth's surface in a year is approximately 1000 times that obtained from burning all the fossil fuels extracted during the same period [3]. Consequently the use of solar power in residential buildings has enormous

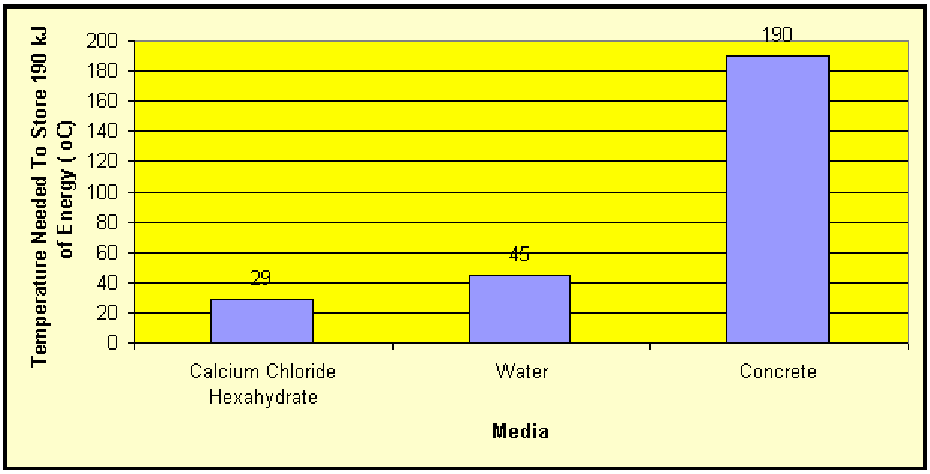

Figure 1. Comparison of heat storage variants

potential for reducing CO_2 emissions.

Interest in renewable energy has increased rapidly throughout the world, an example of this is the U.S. Government's Million Solar Roof Initiative whose objective is to install a million solar roofs by 2010. However there are several major problems with harvesting solar energy; it's availability is unpredictable, intermittent and is often subject to interruptions due to changes in weather. Due to this a form of thermal storage is required to match supply with demand.

Thermal storage can be accomplished either by using sensible heat storage or latent heat storage. Sensible heat storage has been used for centuries by builders to store thermal energy, but a much larger volume of material is required to store the same amount of energy in comparison to latent heat storage. This fact is illustrated figure 1. Calcium chloride hexahydrate is a PCM and at its melting point it can store/release 190 kJ of energy. To store the same amount of energy water would have to be heated to 45°C and concrete would have to be heated to 190°C.

Phase change materials are used in a wide range of applications - from thermally stabilized suits to building insulations and extraterrestrial space applications.

The most popular application the is heat storage system integrated into a renewable or heat recovery system used for space or process heating, air conditioning or refrigeration.

Heat storage is required when a shift occurs between the moment of availability of energy and the moment of consumptions. Energy is stored in PCMs using a variety of methods and coming from a variety of sources: waste heat, excess refrigeration capacity, night-time refrigeration, co-generation facilities, etc. Energy is released the next day (or whenever needed) for air conditioning, process cooling, or process/residential heating. PCM solidifies inside PCM-filled spheres or cylinders installed in large tanks. PCM Thermal Solutions Thermal Storage Systems generate energy cost savings and environmental benefits by using low cost off-peak electrical energy. PCM Spheres can be installed around the world in schools, hospitals, airports, office buildings, churches, government offices and industrial plants.

2. Classification and range of applicability

Spheres of various diameters (75 mm is most common) can be installed in almost any shape or size of storage tank fiberglass, steel, concrete, atmospheric or pressurized; above grade or buried. Flexibility is the key to the application of PCM-filled containers in retrofit and new construction situations where thermal storage was not possible before. In addition, PCM containers can be placed in existing tanks formerly used for storage of other materials.

Phase change materials (PCMs), currently under research and development, can smooth daily fluctuations in room temperature by lowering the peak temperatures resulting from extreme external daily temperature changes. PCMs reduce home heating or cooling loads, thereby producing energy savings for the consumer, and ultimately reducing the need for new utility power plants.

PCMs are solid at room temperature. When the temperature becomes warmer, PCMs liquefy and absorb and store heat, thus cooling the house. Conversely, when the temperature drops, the material will solidify and give off heat, warming the house. By incorporating PCMs in the building envelope, they absorb the higher exterior temperature during the day, and dissipate the heat to the interior at night when it is cooler.

Properties of PCM that are desirable for residential use include: (1) A melting temperature above 25°C (77°F), (2) material is low cost, (3) not toxic, corrosive, or hydroscopic, and (4) commercially available in sufficient quantities for producers to incorporate into ordinary building materials.

Researchers have identified a number of materials that meet most of the specifications. For example, paraffin compounds (linear crystalline alkyl hydrocarbons) are commercially available from petroleum refining or polymerization. Some manufacturers have demonstrated

processes that successfully incorporate paraffin beads into wallboard. However, more research is needed before the technology can be marketed.
PCMs can be broadly classed as Organic and Inorganic.

2.1. Organic phase change materials

Organic Phase Change Materials (PCMs) can be Aliphatic or Other Organics. Users rarely specify the use of Organic PCMs. Latest™ can offer Organic PCMs in low temperature range. Organic PCMs are expensive and they have average Latent Heat per unit volume and low density. Most items in organic PCM range are combustible in nature. They also have a wider range of Melting Point. Some customers specify organic PCMs and we offer them as per PCMs as per their requirement. You need specify the desired Melting Point only.

2.2. Inorganic phase change materials.

Inorganic Phase Change Materials (PCMs) are generally Hydrated Salt based materials. Hydrated salts have a number of hydrates and an anhydrous form leading to stratification of material and loss of Latent Heat recovery with time. Hydrated salts also have a sub-cooling tendency. Old generation PCM manufacturers managed to add performance-enhancing agents. These additives do help in delaying the degradation of PCMs for say 100 cycles or thereabout. However, they do not address the basic reasons due to which sub-cooling and degradation happens. Earlier researchers emphasized that it is beneficial to use impure grades of base material as it promotes the nucleation and prevents sub-cooling. However, impurities also promoted nucleation of undesirable hydrates leading to stratification. Experts on crystallography have managed to identify the “Preferred Crystal Nucleation” method. It consists of a “Cold Finger” that nucleates and promotes the growth of desired crystals and “Detoxification” or “Selective Elimination” whereby any impurity that promotes the growth of undesirable crystals is removed. The current methods of Phase Change Material (PCM) manufacturing are like the new generation “Combination Drugs”.
The main parameters of phase change materials are:

- heat of fusion – the amount of heat required to melt 1 kg of phase change material, expressed in kJ/kg
- duration index, the interval of time required to change the phase

In table 1 are listed a series of commercially available phase change materials

Table 1. Phase changing materials commercially available

Melting point	Grade of PCM	Useful range	Latent heat	Latent heat in useful range	Specific gravity
-50°C	Freezer Salt	-60 to -40°C	325	395	1.3
-23°C	Freezer Salt	-30 to -15°C	330	380	1.2
-16°C	Freezer Salt	-25 to -05°C	330	380	1.02
-50°C	Freezer Salt	-60 to -40°C	325	395	1.3
-23°C	Freezer Salt	-30 to -15°C	330	380	1.2
-16°C	Freezer Salt	-25 to -05°C	330	380	1.02
4°C	Preservation	00 to 10°C	105	135	1.4
8°C	Solar	15 to 21°C	175	210	1.5
21°C	Solar	18 to 24°C	175	210	1.5
30°C	AC-Backup	22 to 36°C	210	250	1.4
31°C	AC-Backup	22 to 36°C	210	250	1.3

2.3. Phase change slurries

Effective heat exchange with the PCM requires a large surface area to volume ratio in the PCM heat exchanger. One way to achieve this is to break the PCM into small particles and wrap each particle in its own heat exchange surface. This process is called micro-encapsulation. This technology has been used by others to embed PCM material into wall boards for houses and into concrete. Phase change slurries are obtained by dispersing a microencapsulated PCM (particle diameter 5-20 μm) with a heat carrier fluid (e.g. water).

Thermal behavior of phase change slurries subject to a complete heat storage – heat release cycle is depicted in figure 2.

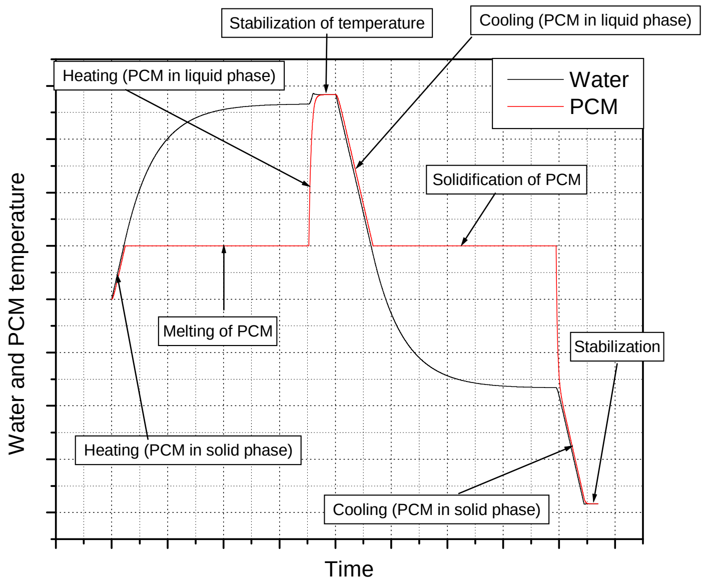

Figure 2. Time dependence of the components temperature in a phase change slurry

3. Conclusions

Phase changing materials are a convenient alternative for energy storage, especially integrated into renewable energy applications such as solar. Heat storage accomplished through usage of phase changing materials correlates the consumption of energy with the availability. Phase changing materials can be used in application such as:

- Thermal energy storage
- Conditioning of buildings, such as 'ice-storage'
- Waste heat recovery
- Off peak power utilization
- Heat pump systems
- Space applications

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