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Free cooling with phase change materials (PCM)

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Abstract. Phase change materials (PCM) are described along with some of their advantages in air conditioning installations, particularly with regard to taking advantage of the free cooling that can be obtained from the ambient air, by using either sensible heat or evaporation. Certain installations are described and the paper concludes by stating that PCMs in microcapsules will facilitate the use of free cooling.

Introduction

Phase change materials (PCM), de to their ability to accumulate a large amount of thermal energy at a given temperature, are considered ideal for use in air conditioning installations for both the regulation of capacity and increasing energy efficiency by enabling compression systems to work at the coldest hours of the day and to take advantage of night-time electricity prices [1]. Chey can also be used in cogeneration and trigeneración systems, enabling the year-round operation of these installations [2]. It is also considered that they could be of great use in air conditioning, taking advantage of the latent and significant "free cooling" of the air as well as evaporation. The objective of this paper is to attract attention to these ideas in order to foster the development of new applications, which are important for the desired development of renewable energies.

Different systems have been used to contain PCMs, depending on the fluid used. Air has been contained in plastic recipients of different shapes and sizes such as plates and cylinders, glass containers such as translucent brick and metal containers such as drums with copper pipes and aluminum fins. When the fluid used was water, drums have been used with copper pipes and aluminum fins, with the PCM between the fins and plastic coils of pipe with the PCM on the outside or plastic pipes with the PCM inside the pipes. Figure 1 shows the different types together with a heat exchanger/accumulator, made up of two circuits alternated for the primary and secondary fluids.

Some of the installations in which we have participated are: experimental huts with translucent Trombe walls and PCM in the other walls, telephone boxes and centers with traditional cooling systems resting on PCM banks, telephone boxes with a water circuit *and* drums with the PCM on the outside or with an air circuit and drums with PCM in the pipes. Installations have been built with evaporative systems, with the PCM in cylinders, in thin plates as can be seen in figure 2 or inside the drum pipes. It is through that they could be placed inside the actual evaporation system, [3] to [6].

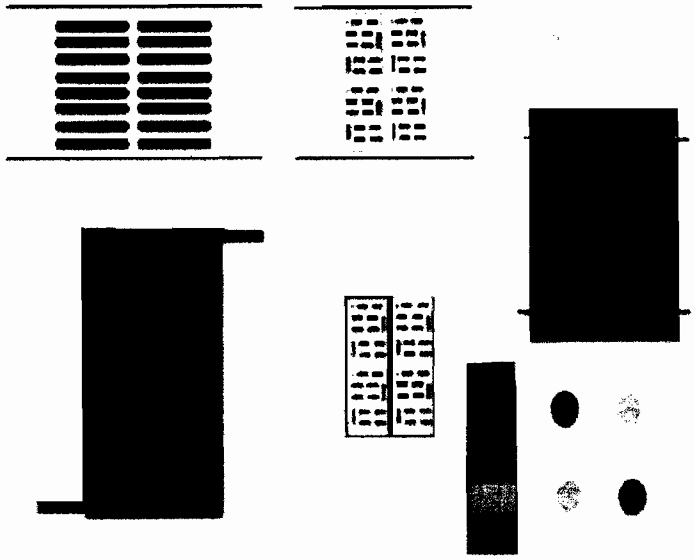

Fig 1. Different types of PCM containers used

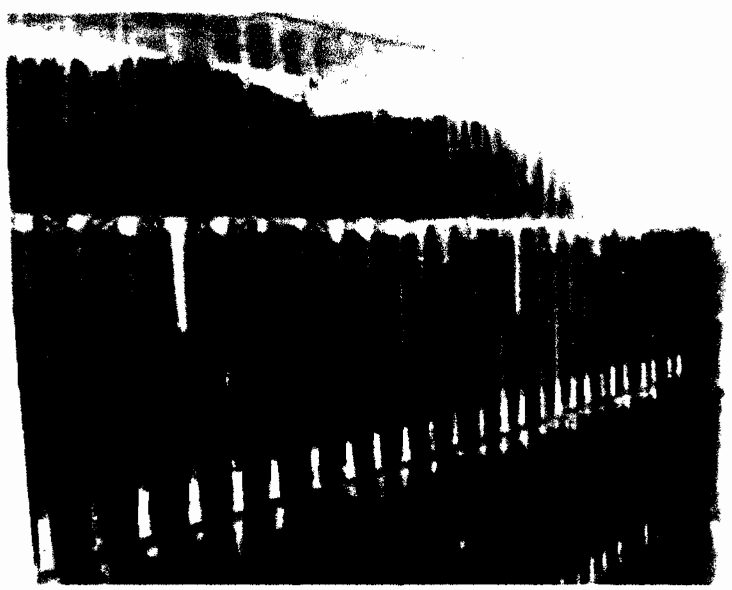

Fig 2. Evaporative system with PCM in thin plates.

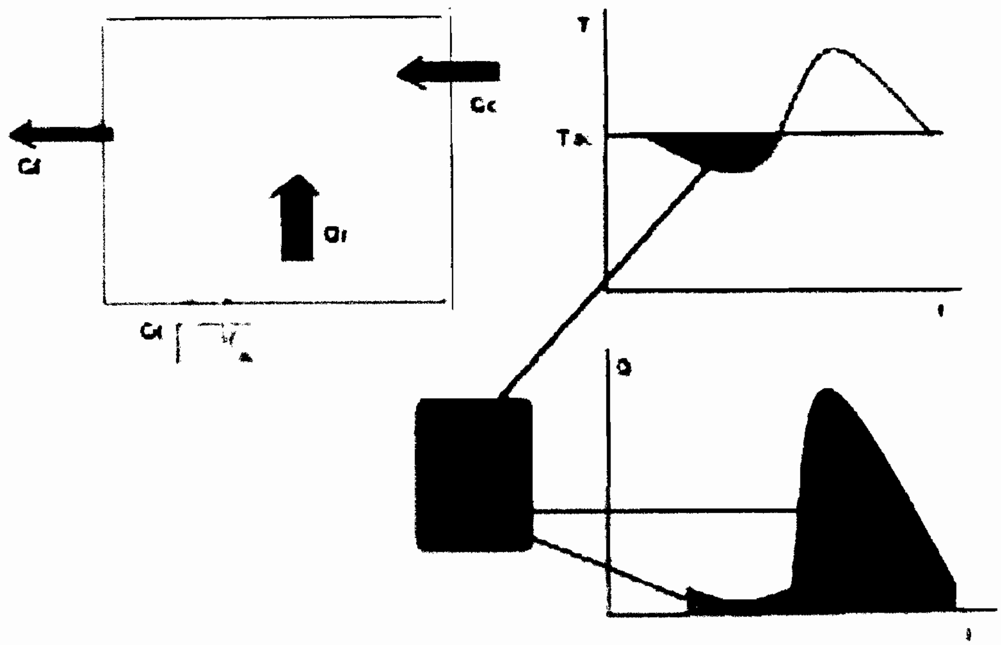

Fig 3. Diagram of the principle of use of free cooling in air conditioning systems

Experimental

Figure 3 is a diagram of the principle of air conditioning installations in which the significant (such as latent or evaporative) free cooling provided by the ambient air can be taken advantage of and returned to the environment, used for renewal of air or for extraction, along with other contributions such as the cold that enters due to conduction at night or the heat that enters through the walls at certain times of the year and internal charges.

In many stand-alone installations, cooling and heating may both be required on a daily basis but at different times of day, not coinciding with thermal charges. The thermal inertia of buildings and their air conditioning installations can be taken advantage of using PCMs, which can store large amounts of heat or cold in small volumes. In certain stand-alone installations, such as sports centres or large stadiums, large amounts of cooling are required in short periods of time. In these installations the accumulation of cold is very important, whereas in large greenhouses heat is required at night and it is available in excess during the daytime; these are just a few examples of where PCMs can be used for air conditioning.

Below are a few examples of how they can be used:

Telephone boxes

Figure 4 is a rough diagram of a telephone box, with a device that is hung on the outside or placed on top that can take advantage of free cooling. It is made up of a drum or set of recipients containing the PCM, a mechanical system for the impulsion of air, a regulation and control system that enables the intake of outside air when the temperature is lower than that of the PCM. This cold air solidifies the PCM and when it melts afterwards it cools down the inside of the cabin. The intake is closed when the outside air temperature is higher than that of the PCM phase change and air is re-circulated through the PCM and the area to be cooled, melting the PCM.

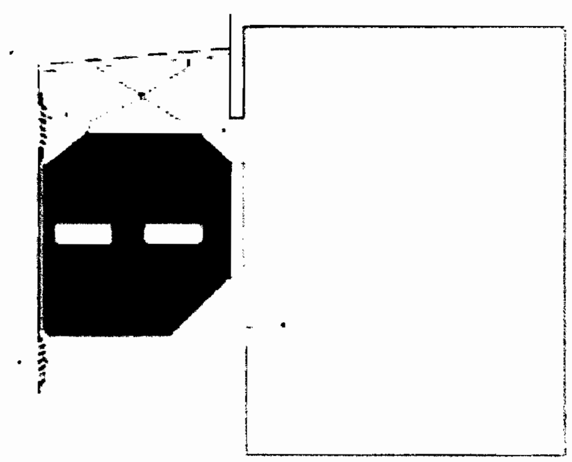

Fig 4. Taking advantage of free cooling in a telephone box

Industrial buildings

Figure 5 is a diagram of the cooling of an industrial building with an indirect evaporative system, made up of the classic evaporation system with its filling, a water drum that is cooled down with forced humid air and an exchanger/accumulator with a double water circuit. The primary circuit re-circulates the water from the evaporative system and the secondary circuit passes the water to cool the industrial building's unit heaters.

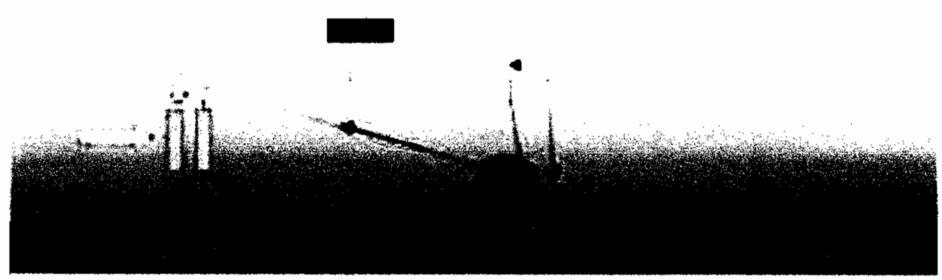

Fig 5. Taking advantage of free cooling in an industrial building and evaporative cooling

Discussion

In installations that require temperatures close to the average of the dry or humid ambient air temperatures (from 22° to 28°C in the Iberian peninsula), the free cooling of the air can be used for air conditioning, using PCMs with phase changes a few degrees below these temperatures: at night the PCM solidifies and during the day it melts, returning the cold accumulated. In order to reduce the volume of PCM needed in the event that cooling is required, (such as in communications centres and transformer rooms, in which electrical equipment gives out heat 24 hours per day), the cold of the outside air at night can be used for the cooling of enclosures. The only foreseeable problem is that dust could enter the air, but this can be avoided by using adequate filters and maintaining them correctly. In the event that the temperatures required are lower than those provided by the environmental air temperature, in dry climates evaporative systems can be used, which in many cases make it possible to significantly reduce the amount of PCM required.

Two main problems have arisen in the systems studied over the last few years: the cost of PCMs and their retention systems and the transmission of heat from these materials to the thermal fluid. In small installations, air has proven to be the simplest and cheapest fluid and plastic plates or bags can be used with thicknesses of less than 2 cm. For higher-power systems, it is necessary to use water in cylindrical tanks with spiral coils with a diameter of approximately 20 mm, such as those indicated in figure 6, with a single circuit or a double water circuit.

The desired storage capacity is easy to determine in each case when the latent heat of the PCM used is known. The charging and discharging capacity is slightly more complex, as it depends on the difference in temperature between the fluid and the PCM, the exchange area and the overall transmission ratio. It is considered that with temperature differences of about 3°C, overall coefficients of about 40 W/m2.K, with separations between pipes of approximately 3 pipe diameters; charge and discharge times of about ten hours are obtained, which are ideal for the main applications [9]. Working with differences of less than three degrees is considered problematic from the point of view of heat transmission and the PCMs themselves, as they do not usually have a fixed phase change temperature as with pure products but rather a phase change plateau or an interval of several degrees.

It is very possible that new air conditioning systems will be developed that incorporate PCMs in microcapsules, removing the need for accumulation tanks. More information about this subject is available in papers [8] and [9].

Conclusions

Phase change materials or PCMs can facilitate the widespread use of "free cooling" in a wide range of large air conditioning installations, contributing to the desired sustainable development of the planet, thereby helping to reduce the deterioration of the ozone layer and global warming.

The way it is used is important, because this shall determine its cost and operational reliability. It can be incorporated into walls, taking advantage of the natural movement of air in convective buildings or Trombe walls, using forced air with or without an evaporative system or with water and large accumulation tanks. And it is possible that the need for these tanks can be eliminated by introducing PCMs in microcapsules in the water distribution circuit.

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