# Phase Changes Materials and Controls in Thermodynamic Models

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**References**

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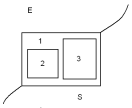
## A container with a heat storage system




The model is a supposed to be a container 1, in which we have inside two bodies: 2 is PCM and 3 a cavity. The container is supposed to be in thermal contact with a substrate S with a constant temperature and the environment E, having an oscillating temperature. The equations of the volume balance for the three bodies are:

$$C_1\dot{T}_1 = \alpha_{1E}S_{1E}[T_E(t)-T_1(t)] + \alpha_{1S}S_{1S}[T_S - T_1(t)] + \alpha_{12}S_{12}[T_2(t)-T_1(t)] + \alpha_{13}S_{13}[T_3(t)-T_1(t)]$$

$$C_2\dot{T}_2 = \alpha_{12}S_{12}[T_1(t)-T_2(t)]$$

$$C_3\dot{T}_3 = \alpha_{13}S_{13}[T_1(t)-T_3(t)]$$

The parameters we use for calculations are $C_1 = 2.0\times10^6\ JK^{-1}$, $C_2 = 4.18\times10^6\ JK^{-1}$, $C_3 = 1.0\times10^5\ JK^{-1}$, $\alpha_{1E}S_{1E} = 50.\ W\,K^{-1}$, $\alpha_{1S}S_{1S} = 20.\ W\,K^{-1}$, $\alpha_{12}S_{12} = 100.\ W\,K^{-1}$, $\alpha_{13}S_{13} = 20.\ W\,K^{-1}$, $m_{PCM} = 10^4\ kg$ and $H = 333.\ kJ/kg$. Note that we suppose a high value of the exchange parameter $\alpha_{12}S_{12}$ between container and PCM, imaging a high value of the surface between the bodies. The substrate S is at a fixed temperature, $T_S = 270.0\,K$, that is the temperature of a permafrost soil for instance.

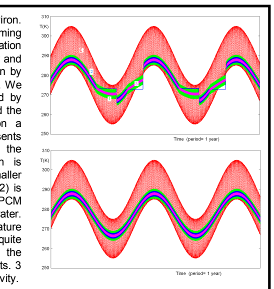
### Intro

The study of the thermal behaviour of macroscopic systems is quite important because of its usefulness in simulating the temperature behaviour and heat exchanges of local environments. Due to the current condition of an increasing average temperature coming from the global warming, these simulations could help in offering new solutions to reduce the energy consumption and prevent side effects. Here I am proposing and discussing the thermal behaviour of models, which simulate macroscopic structures having some parts consisting of Phase Changes Materials (PCMs). These are materials able to store the thermal energy. Among the various methods for energy storage, those based on the latent thermal energy of PCMs are widely considered as able to provide highly effective systems [1].

## PCM

- Among the various methods to store energy, the latent thermal energy storage using a Phase Change Material (PCM) is widely considered as a highly effective way, due to its advantages of a high density of energy stored and its isothermal operating characteristics during the solid/liquid phase change. In a latent heat storage system, the energy is stored during the melting and recovered during the solidification of a PCM substance.
- For what concerns the use of PCMs in energy storage systems, it is necessary to note that some practical difficulties can arise because these materials usually have a low thermal conductivity and a poor stability of properties under extended cycling. Sometimes phase segregation and subcooling can happen. Over the past years, studies have been performed to examine the performances of various latent heat thermal energy storage systems [S.D. Sharma and K. Sagara, Latent heat storage materials and systems: a review, Int J Green Energy, Vol.2, pp:1–56, 2005]. Among the organic materials, the use of fatty acids as PCM has gained a certain interest in recent times.

The temperature of environ. E is oscillating assuming that the solar radiation changes during the day and over the year, as shown by the curve (E) in Figure. We see E band composed by the daily oscillation and the seasonal oscillation on a year. Band (1) represents the temperature of the container walls, which is oscillating too with smaller amplitude. The curve (2) is the temperature of the PCM material, assumed water. Note that the temperature (2) is constant for a quite long period until the material freezes or melts. 3 is temperature of the cavity.

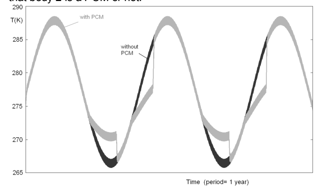



### Models and simulations

As a possible approach to simulate the behaviour of macroscopic volumes, which include some energy storage systems with PCMs,
I am proposing the use of models composed of several parts, each obeying the laws of thermodynamics. These parts are interacting with heat exchanges. Some parts are in connection with the external environment. The thermal behaviour of the models is obtained by means of a simulation based on lumped elements, where the description of spatially distributed physical systems is realized through a topology consisting of discrete entities. Under certain assumptions, the simulation with lumped elements, originally developed for electrical systems, is suitable to solve and determine the behaviour of a distributed system [2]. This approach has been already proposed for systems under period conditions [3]. Here, besides PCMs, passive and adaptive controls are included in the models to study the temperature optimization inside specific environments.

- As PCMs perform best in small containers, they are usually subdivided in cells of a proper packaging material. This materials needs to conduct heat well and durable enough to withstand frequent changes in the storage material's volume as phase changes occur. Moreover, the packaging must resist leakage and corrosion. Micro-encapsulation has naturally become the obvious packaging choice, after the early macro-encapsulation with large volumes revealed itself as inefficient, due to the poor thermal conductivity of most PCMs. Micro-encapsulation allows the PCMs to be incorporated into construction materials, such as concrete, easily and economically. Micro-encapsulated PCMs also provide a portable heat storage system. By coating a microscopic sized PCM with a protective coating, the particles can be suspended within a continuous phase such as water. This system can be considered a phase change slurry.
- PCMs have been considered for thermal storage in buildings since before 1980. It was proposed and studied the integration of a PCM in construction materials and test them in real buildings to check improvements. In fact, the walls and ceilings of a building offer large areas for passive heat transfer and for the storage of energy.

- Temperature in the cavity 3 has a different behaviour in the case that body 2 is a PCM or not.




Note that the minimum temperature in the cavity 3 is always 5 degrees above the minimum temperature reached by the system without PCM. The simulation shows that with a suitable choice of PCM quantities, it is possible to manage the excursion of the temperature inside the cavity (and also of the container walls).