PHASE-CHANGE MATERIALS

1. Introduction

A phase-change material (PCM) stores and releases heat when melting and freezing, which occurs at given temperatures. The programs VOLTRA and BISTRA allow simulating the thermal behaviour of objects in which such PCM's are embedded. As an example, the temperature course in 2 identical rooms, one without and one with PCM is simulated.
2 cases are discussed:

1. with a pure PCM,
2. with a board that is commercially available.

3. Case 1 - data

VOLTRA data box_with&without_pcm.vtr

Figure 1 show 2 half rooms. The internal dimensions are 2 m x 2 m x 1 m.
The walls contain (from outdoors to indoors):

- 10 cm of thermal insulation (λ = 0.025 W/mK, ρ = 30 kg/m^3, c = 1000 J/kgK)
- 14 cm of brickwork (λ = 0.6 W/mK, ρ = 1350 kg/m^3, c = 840 J/kgK)
- 1.5 cm of gypsum (λ = 0.3 W/mK, ρ = 900 kg/m^3, c = 1000 J/kgK) for the right room
- 1.5 cm of PCM (λ = 0.134 W/mK, ρ = 767 kg/m^3, c = f(θ)) for the left room.

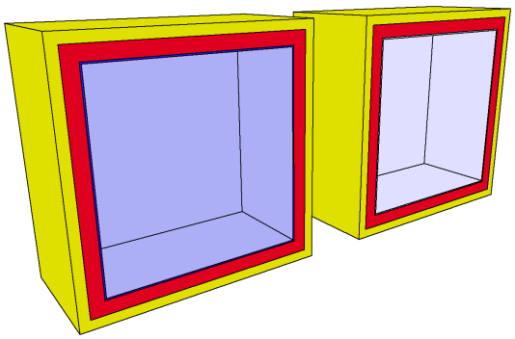

Figure 1. 2 half rooms, left one with internal PCM layer, right one with internal gypsum layer.

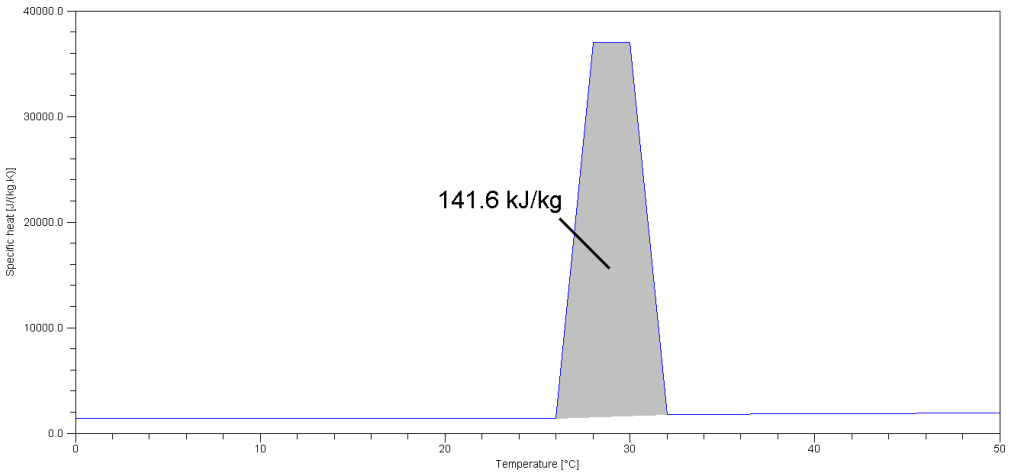

Figure 2. Specific heat of PCM as a function of temperature

The PCM has a latent heat content of 141.6 kJ/kg. The phase change occurs in the range of 29 °C - 31 °C. The specific heat in the solid state is 1420 J/kgK. The specific heat in the liquid state is 1802 J/kgK at 32 °C and 1902 J/kgK at 50 °C. This data are used to build the function file PCM1.FCE shown in Figure 2.

The file PCM1.FCE is a simple text file with the following contents:

0 1420
26 1420
28 37010
30 37010
32 1802
50 1902

Each point on the line contains a temperature value and a specific heat value. The function values are derived in order to obtain an area (grey area Figure 2) under the function line corresponding to the PCM latent heat content.

The temperature of the environment around the rooms is assumed to be 30 °C.
The external surface heat transfer coefficient is 13.5 W/m^{2}K.

Inside the rooms a sinusoidal heating/cooling power is released (Figure 3). The rooms with unknown temperature are simulated using the type BC_FRE_S with a global heat transfer coefficient = 5 W/m^{2}K.

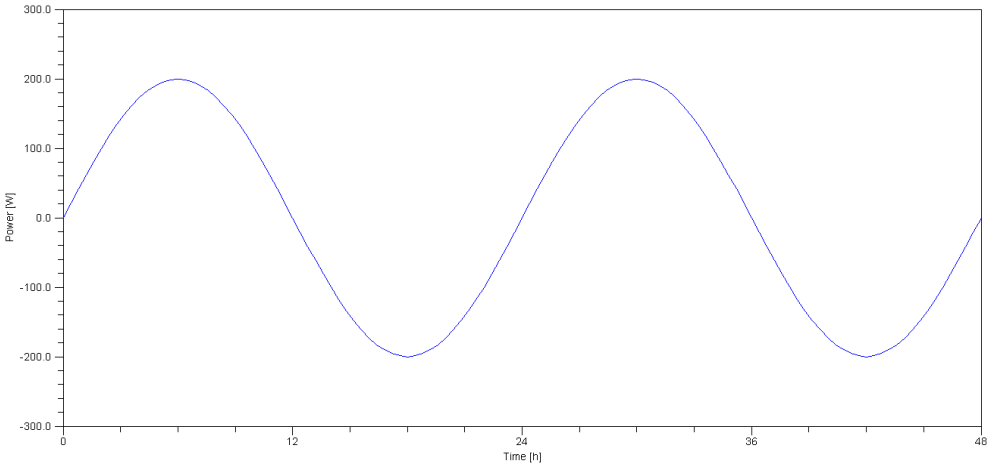

Figure 3. Heating/cooling power released in the rooms.

The simulation is done for 2 days using a 10 minutes time step, with start-up duration of 3 days to get harmonic conditions.

Case 1 - results

Figure 4 shows the temperature in the 2 rooms, in the gypsum board and in the PCM (at a depth of 5 mm from the indoors).

Figure 5 shows the temperature distribution in the 2 rooms at hour 31.

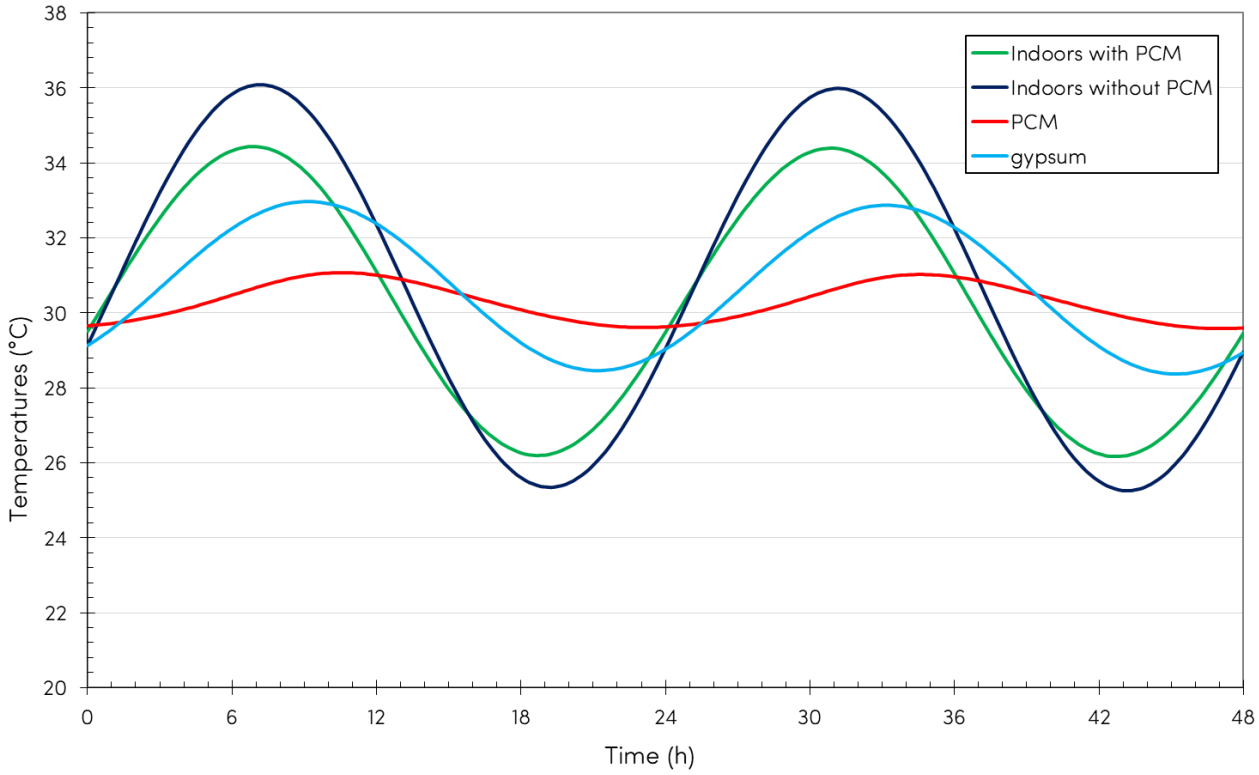

Figure 4. Temperature course in the 2 rooms, in the gypsum and in the PCM.

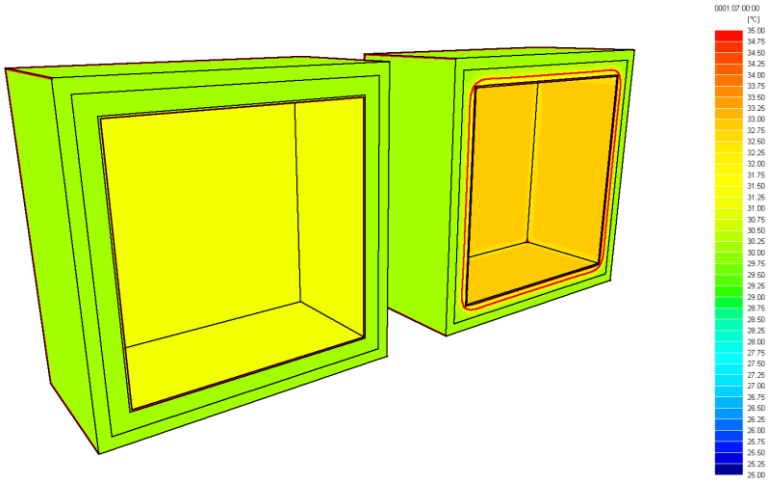

Figure 5. Temperature distribution in the 2 rooms at hour 31.

4. Case 2 - data

VOLTRA data box_with&without_smartboard.vrt

The case 2 data are almost identical to the case 1 data. The differences are:

- The specific heat of the PCM. Figure 6 shows the specific heat as a function of time for a commercially available board (Micronal PCM Smartboard 23/26). The latent heat content is much lower than the pure PCM material used in case 1. The phase change occurs in the range of 23 °C - 26 °C
- The outdoors temperature is 25 °C instead of 30 °C.

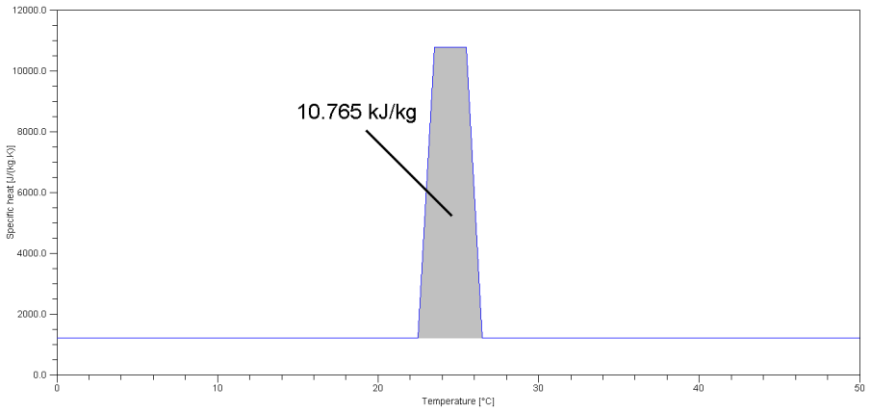

Figure 6. Specific heat of the Micronal PCM Smartboard 23/26 as a function of temperature

Case 2 - results

Figure 7 shows the temperature in the 2 rooms, in the gypsum board and in the Smartboard (at a depth of 5 mm from the indoors).

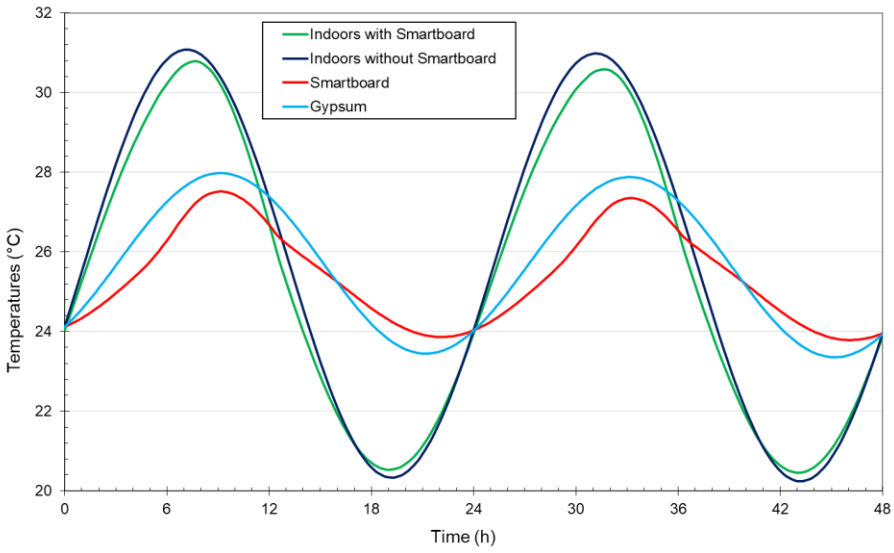

Figure 7. Temperature course in the 2 rooms (with and without PCM)