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PHOENICS Demonstration Example using PHOENICS-3.6.2 [2006]

Thermal Analysis of a Transportation Container

Temperature control is a major concern of goods transportation, i.e. food, medicine or biological materials etc. To develop customized, cost-effective temperature-control solutions to meet regulatory compliance standards, thermal package engineers need to know which packing materials should be used and what the best-conditioned temperatures are before shipping.

The following case demonstrates the ability of PHOENICS to analyse the thermal behaviour of components stored within a thermal transportation container. The geometry components are shown in Figure 1, in which the case is simplified for demonstration purposes. Water product is placed in the centre of a polyurethane box surrounded by refrigerated gel packs on six sides, and frozen gel on the top and bottom. The air gaps are taken into consideration between the gel packs and box walls, but no gaps are assumed between gel packs themselves and the product.

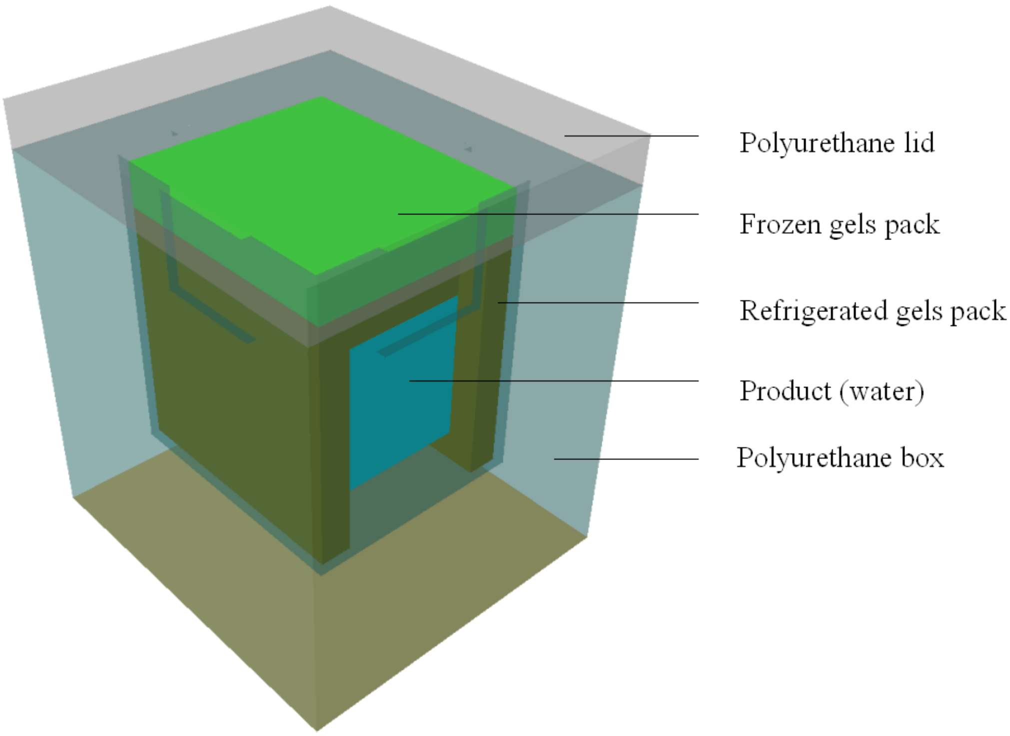


Figure 1. Geometry of thermal container

For the purposes of this case, each component is “pre-conditioned” with the following temperatures as shown in Table 1 before packing and shipping.

Table 1. Initial temperatures of thermal box components

component	polyurethane box and lid	frozen gel	refrigerated gel	water	Air
Temperature ^{o}C	22	-22	5.5	6.4	22

The box surface is assumed to have equilibrium temperature as the ambient, which changes periodically from day to night in 72 hours shown the Figure 2.

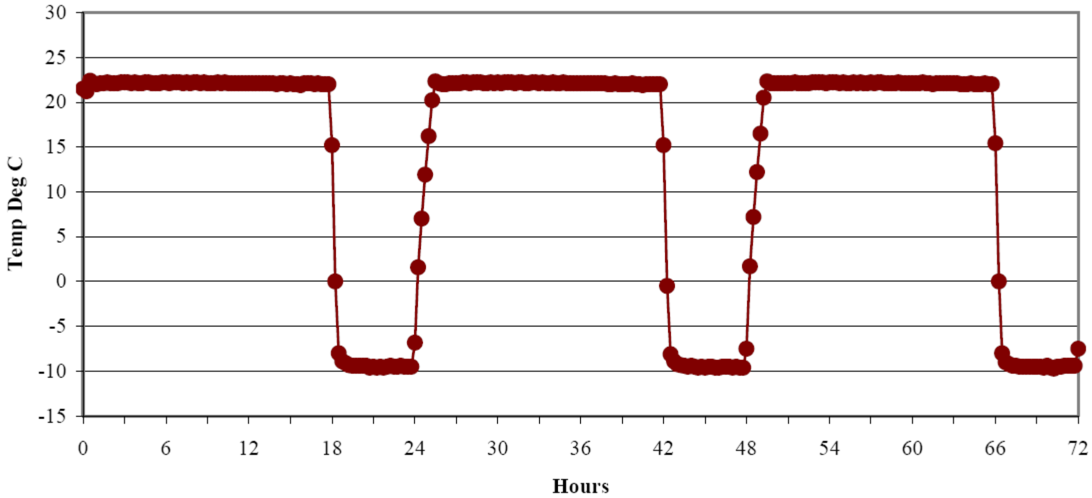
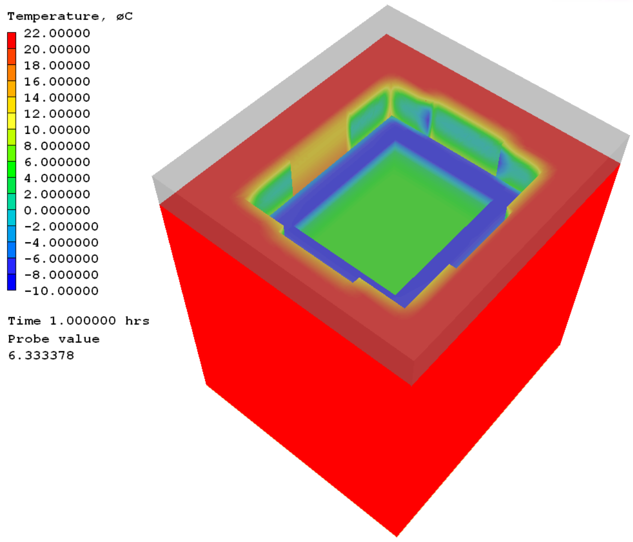


Figure 2. 72 hours ambient temperature profile

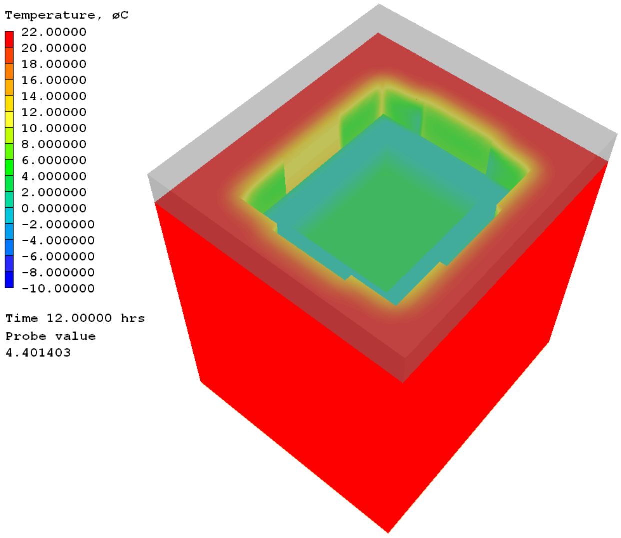
The PHOENICS “INFORM” feature was used to implement the material properties, phase-change, heat release and absorption and the box’s thermal boundary conditions.

The thermal box surface temperatures in Figure 3, shown at different hours, indicate the product temperature is predominantly steady although the polyurethane box itself has been subjected to periodic changes of ambient temperature.

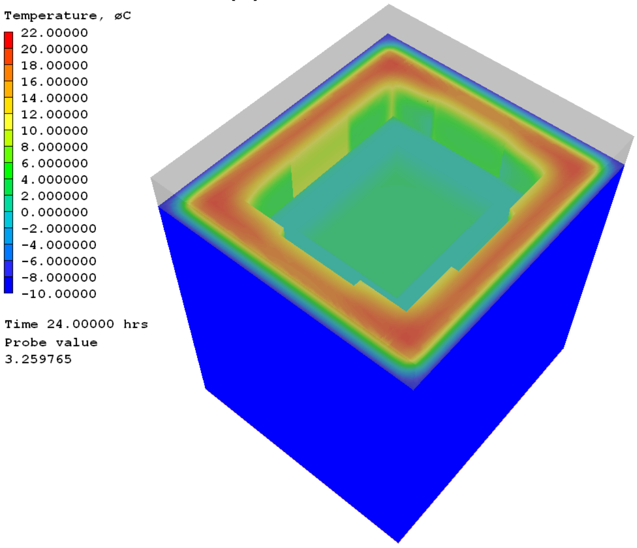
As intended, the effects of these changes have been shielded and stabilised by the surrounding gel materials.



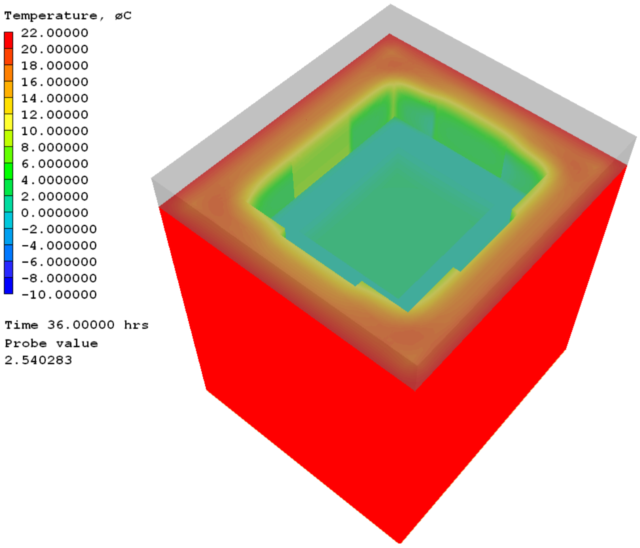
(a) one hour



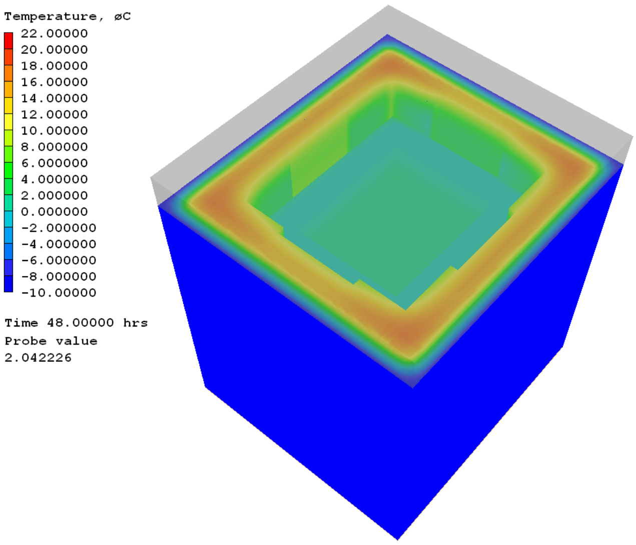
(b) 12 hours



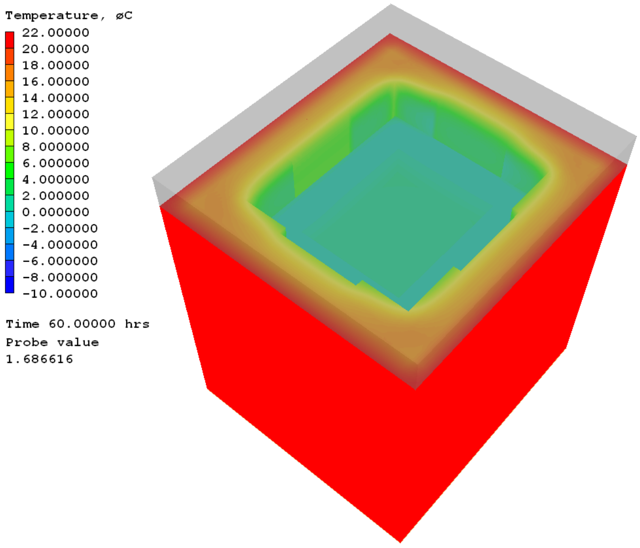
(c) 24 hours



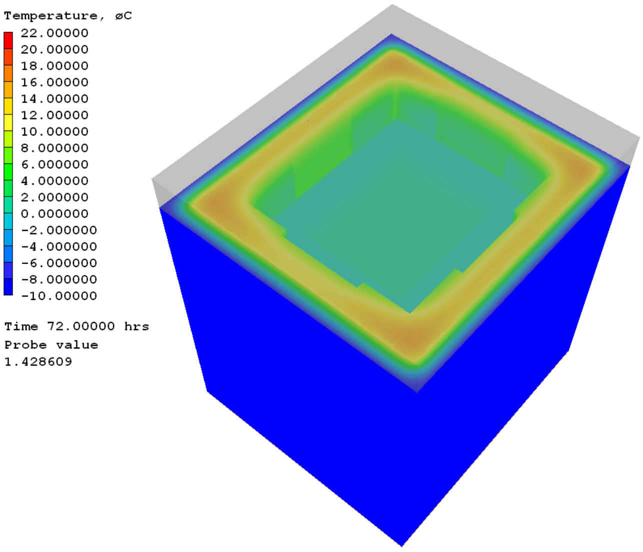
(d) 36 hours



(e) 48 hours



(f) 60 hours



(g) 72 hours

Figure 3. Thermal box surface temperature contours

In Figure 4, the thermal behaviour is clearly shown by point-temperature histories at different positions of the thermal box package. The temperature at the midpoint of the polyurethane wall (yellow) changes periodically due to the direct influence of the ambient. The frozen gel absorbs some heat from the polyurethane wall and raises its temperature from -22 ^{o}C to -0.4 ^{o}C in first ten hours, but then becomes steady (brown). The product (blue) and refrigerated gel (pink) have higher initial temperatures than the frozen gels that were cooling down slowly to about 2 ^{o}C in 72 hours.

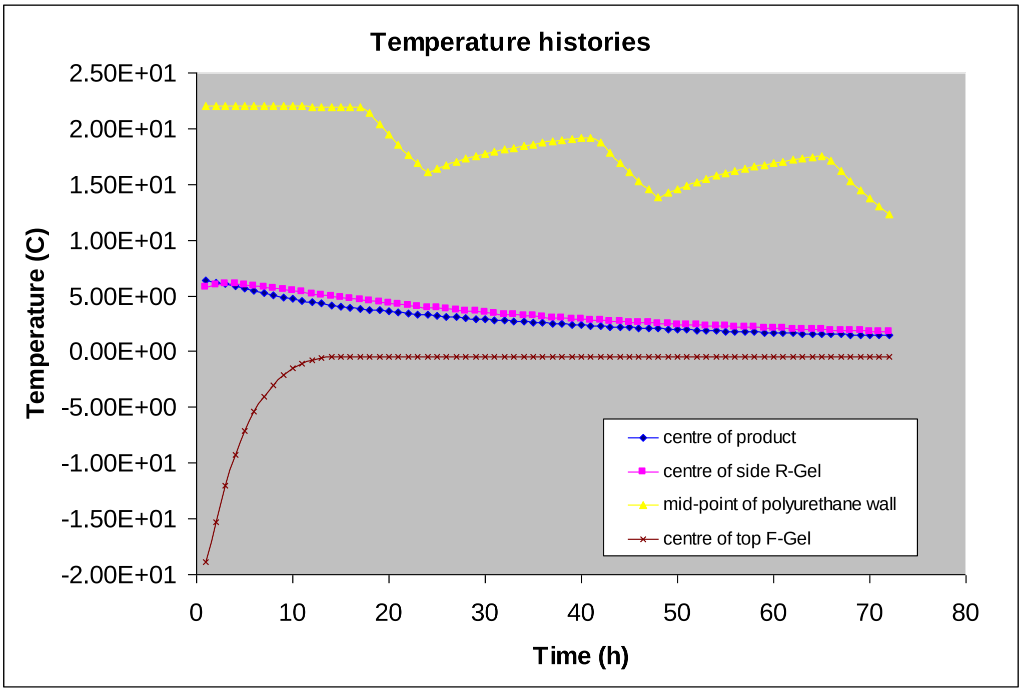


Figure 4. Temperature histories - thermal box

An additional run was carried out for the case in which the gel material was replaced with material having no phase change or very little latent heat. In this case, the product temperature rises constantly, as shown in Figure 5. By contrast it was cooling down in the previous case.

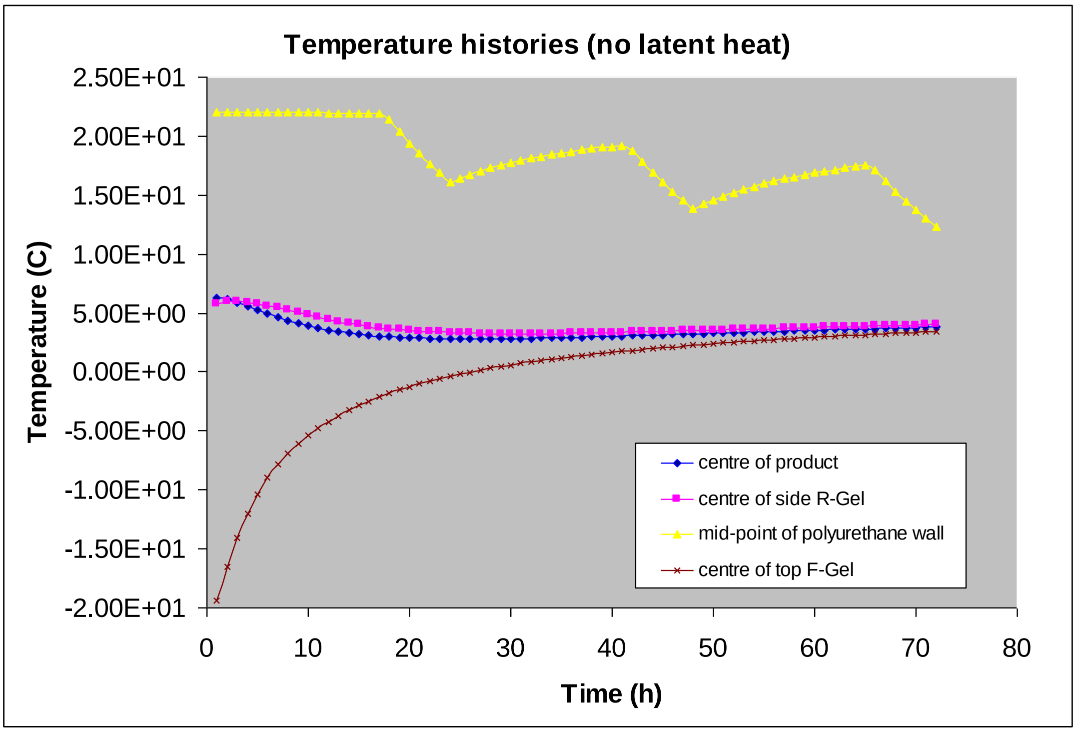


Figure 5. Temperature histories - thermal box (no phase change)

This demonstration shows how PHOENICS can be readily applied to assist engineers when analysing the thermal behaviour of packaging, and to help achieve the most cost-effective solution when designing containers or choosing packing materials, conditioned temperatures or shipping practices.

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