Royal Institute of Technology
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Summation from R&D of various coolants

Since year 2000, the Department of Energy Technology at the Royal Institute of Technology (KTH) has performed several hundreds of experiments and research on thermally controlled transportation boxes using mainly salt based PCM as a coolant. This is a very short summation of some results achieved.

The word PCM stands for Phase Change Material, another abbreviation commonly used is TES-material, standing for Thermal Energy Storage-material.

Package solutions with PCM can be water based coolants using trade names such as Icepacks or Gelpacks etc. Salt hydrate or Paraffin/Wax based coolants are also common. They all have their benefits and drawbacks depending on application and actual requirements.

The energy rejection or absorption that takes place during the material transformation between solid and liquid state is named **latent heat**. The energy that is rejected /absorbed without a phase change is called **sensible heat**. When referring to a PCM the greater part of the energy rejected or absorbed is latent heat and therefor bound to the phase change.

To understand the concept of a thermal transportation package one has to look at it as an energy storage system (i.e. energy flow, in and out through the insulated package walls). Each kilogram of coolant loaded into the box holds a number of Wh. As an example, the latent energy of 1 kg ice is 334 kj/kg = 92,5 Wh /kg , see Table 1 below

PCM	Melting point [°C]	Sensible heat solid [kj/kgK]	Latent heat liquid [kj/kg]	Sensible heat liquid [Kj/kgK]	Storage capacity [from -2 to +13°C] [Wh/kg]
Water based Icepacks	±0	2,1	334	4,2	109
Salthydrate C7	+5	3,6	140	3,6	54
Paraffine RT5	+5	na	na	na	55

Table 1

Today water based icepack solutions are widely used. However their ability to create a safe environment for temperature sensitive products like vaccines (+2°C to +8°C) is restricted. The reason is that icepacks have the wrong melting temperature. The most obvious and critical case is the protection from freezing of the product. As seen above in Table 1 the sensible energy in the liquid phase are almost negligible compared to the latent energy. This indicates that the package ability to maintain the resistance against a lower temperature is depending on the latent energy. Since ice will be freezing at ±0°C (not taken into account the sub cooling that ice undergoes before freezing) the package performance will be very poor regarding withstanding a cold environment.

When coping with a warmer surrounding the use of icepacks is more complex. To be able to use it as protection against high temperatures the icepacks have to be preconditioned to avoid risk of endangering freezing of the product. Since the temperature of melting ice is ±0°C, there has to be a heat flow into the box, balancing the low temperature of the ice. If not, the product temperature will go under +2°C.

A package will maintain its right temperature if correctly designed under the condition that the ambient temperature are relatively constant. A low ambient temperature results in a low heat flow into the package and a high ambient temperature produces a high heat flow.

The configuration of the icepacks doesn't change during a shipment, whilst the ambient temperature is varying. This will result in a variation of heat flow into the package. The same will account for the temperature inside the package. If the ambient temperature variations are large there is a risk for endangering the product.

A way to solve this problem is to use a coolant that melts at +5°C, (i.e. in the same temperature span as the product is required to be stored in (+2°C to +8°C)). This gives the possibility to cover all the interior sides of the box, since there is no need of heat flow balancing a too low cooling temperature. Instead, in this case the heat flow has to melt its way through the coolant walls before reaching the embedded product. As long as the melting occurs, the temperature inside the package will be relatively uniform and within the limits of the product.

This solution is even more beneficial when adapted on a package that needs to be protected from a cold ambient environment. In this case the PCM with a freezing point of +5°C would be ideal. The PCM reject its stored energy (latent energy) to the ambient while freezing. During freezing the temperature will be uniform and within the limits of the product.

Such a PCM would also be ideal when "warm life" is the requirement and will keep the package solution frost proof even at ambient freezing temperatures.

In order to clearly illustrate what has been described above, we share in Annex 1 the results from two comparative tests between Icepacks (PCM ±0°C) and a system with ThermoShields (PCM +5°C).

Except for good thermodynamic properties such as high latent heat, stable phase change temperature, small hysteresis, no chemical separation, etc. there are some other practical parameters that the user should be aware of before choosing the coolant. They are shown in Table 2 below. However, it's recommended to check with the manufacturer the contents of respective PCM-coolant for any hazardous issues.

PCM	Lifetime	Environmental	Safety issues	Health warnings
Water based Icepack	Long	Friendly	None	None
Salthydrate C7	Long	Friendly	None	None
Paraffine RT5	Long	Friendly	Flammability	None

Table 2

Regarding the measurement equipment, the accuracy for the temperature monitors has to be better than ± 0.5°C and calibration certificate has to be updated regularly. Of great importance is the placement of the temperature sensors when qualifying the package. The temperature inside a package will not be evenly distributed, there will always be temperature gradients occurring. The magnitude is depending on the ambient temperatures and package design. Sometimes those gradients are larger than 1°C. Because of this a safety margin is applied resulting in a recommendation to avoid the temperature to go under +2°C. This implies that the safety margin at +0,5°C is too close to the freezing point . Furthermore to be able to qualify packages we strongly recommend to use the **ASTM D3103-99: Standard Test Method for Thermal Insulation Quality of Packages.**

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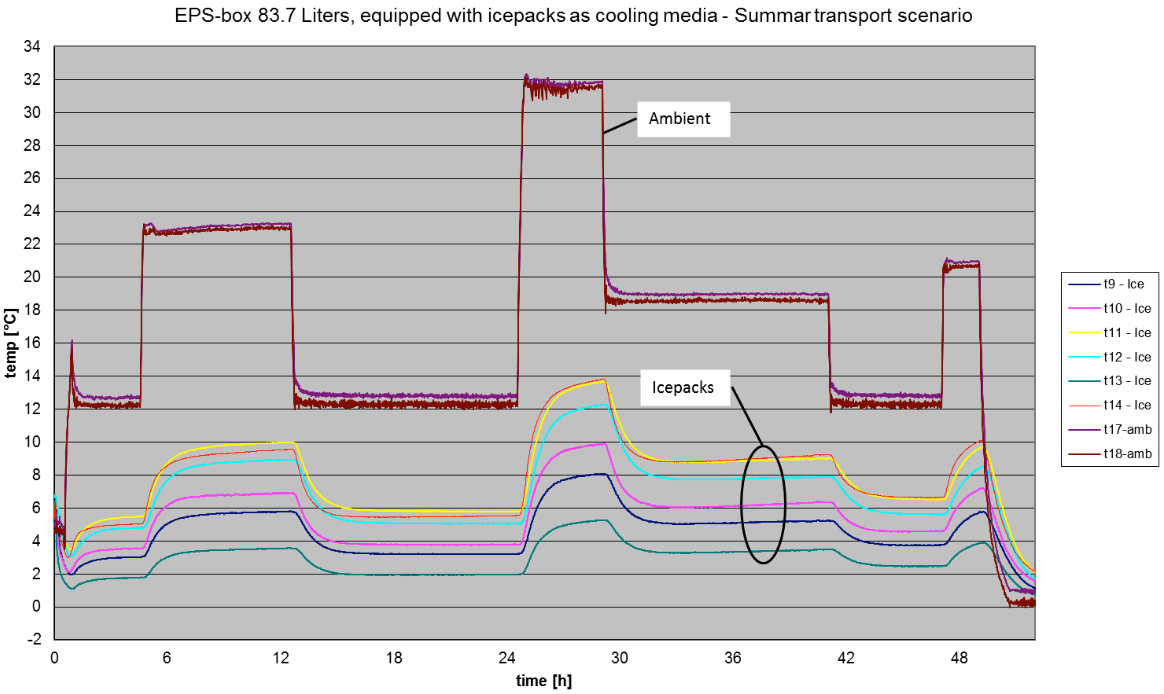
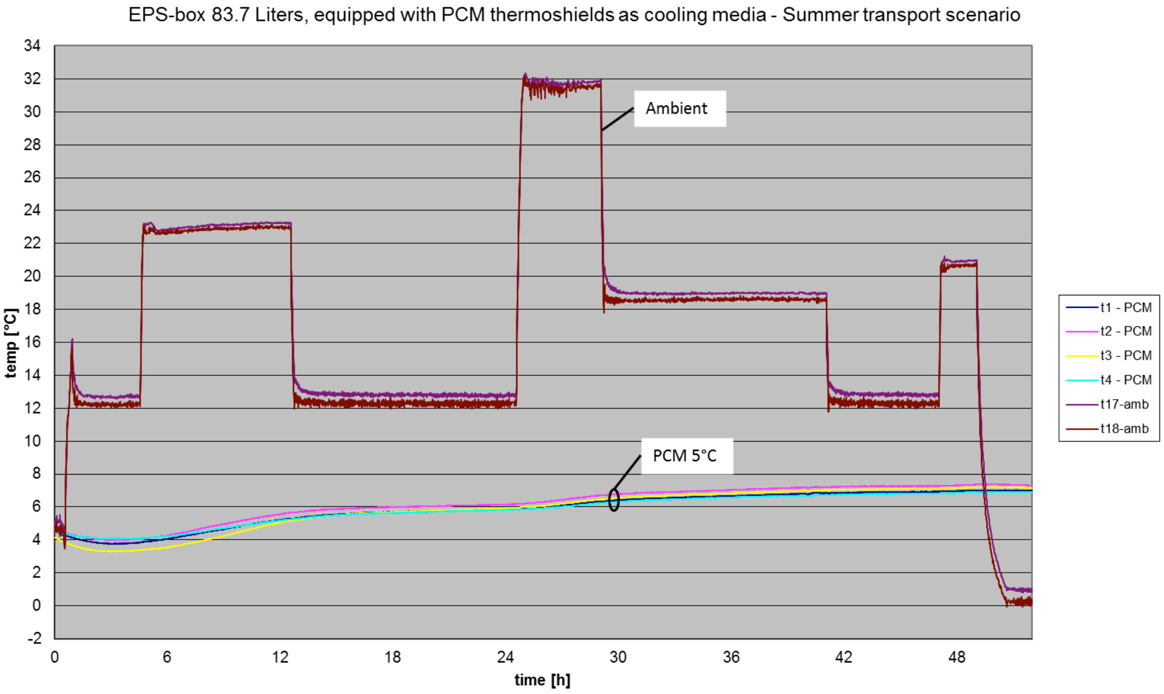
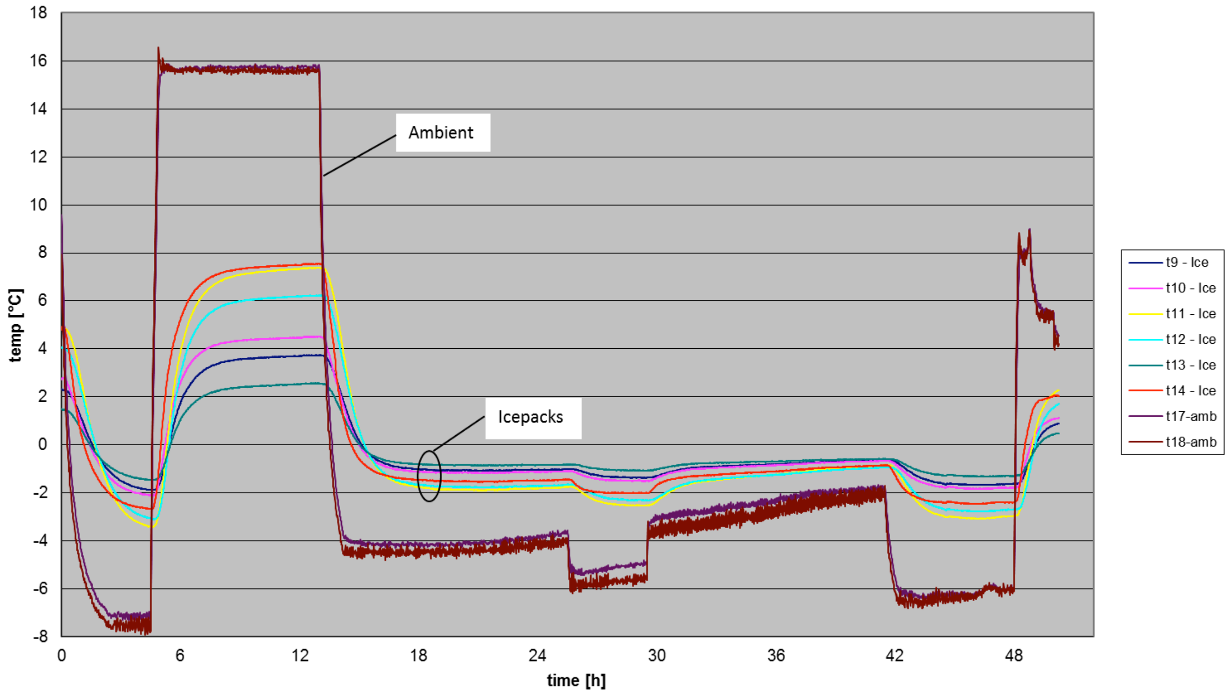
Tests performed at the Royal Institute of Technology, KTH / Department of Energy Technology.
The graphs below show a comparison between Icepacks (PCM ±0°C) and ThermoShields (PCM +5°C) covering all the inner walls of the package. The icepacks were placed under and above the 3 layer bubble plastic wrapped product. Two tests were performed simulating typical ambient temperature conditions during a summer and winter transport scenario. The two test objects were tested parallel in the same climate chamber so that the test conditions were as equal as possible.





EPS-box 83.7 Liters, equipped with icepacks as cooling media - Winter transport scenario



EPS-box 83.7 Liters, equipped with PCM thermoshields as cooling media - Winter transport scenario