Is it time for a change?

Alternatives and selection criteria to water based phase-change materials

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Introduction to Phase Change Materials (PCMs)

The purpose of a complete temperature controlled packaging system is to maintain an interior thermal environment sufficient to meet the product's temperature requirements. The system includes not only the packaging material itself, but the insulation, and passive phase change materials that hold temperature (active refrigeration systems will not be covered here).

Phase Change Materials (PCM) oscillate between solid and liquid phase within a certain temperature range. When the environment’s temperature is higher than that of the PCM, heat transfers from the surroundings to the material, which creates a cooling effect and changes PCM's state from solid to liquid. When the environment’s temperature is lower than that of the PCM, heat transfers from the PCM to the surroundings, generating a warming effect and PCM changes back to its solid state.

That is where a PCM comes in handy. It matches the temperature of the product while it is going through it's phase change, making it ideal for temperature sensitive applications, like:

- Life science/biologics packaging
- Pharmaceutical packaging
- Wine packaging
- Frozen and refrigerated food packaging
- Meat poultry and seafood packaging
- Dairy product packaging

How does a PCM work?

Each material has a defined temperature at which it changes state between solid and liquid. These have specific amounts of thermal energy that are absorbed while solidifying, and released while liquefying. During this process, they maintain their constant level of phase change temperature.

The majority of PCM based cold chain refrigerants use specially developed, bio-based products made from paraffin materials or salt hydrates. Unlike ice, which occurs only at 0°C (32°F), these materials provide, at various temperatures, consistency of energy storage. PCMs’ store as much volumetric latent heat energy as frozen water.

Water-based PCMs vs other passive/hybrid PCMs

At what temperature these changes happen is different based on the makeup of the substance being altered. For example, ice (based on water) melts above 0°C / 32°F, making it change from a solid to a
liquid. Water is also inexpensive, non-toxic and ubiquitous, making it the most commonly employed refrigerant material and the standard for comparison (often with some additives to alter its properties).

**So why not just always use water for the PCM?**

For many years, the industry has relied on water-based passive cold chain packaging systems, where water is present in both frozen and refrigerated states. These systems have suffered from performance limitations resulting in heavy, large, and complicated shippers, that can only transport relatively small amounts of payload, for restricted shipment durations. In addition, these systems pose serious environmental challenges, due to limited reuse and recyclability options.

Even with these major disadvantages, ice has a number of benefits in protecting against high temperatures: the quantity of energy frozen water can store is relatively large versus other materials. Water is also relatively inexpensive, widely available, can easily be gelled, and has a great safety and environmental profile.

A good description for the positives and negatives of refrigerated water PCM is comes from an article in pharmaoutsourcing.com:

> The role of refrigerated water PCM is to protect the product from temperatures below 2°C, due to the presence of ice internally, and anticipated winter conditions externally. However, refrigerated water will maintain 0°C during freezing, and therefore will not protect from product exposure to temperatures below 2°C. Accounting for supercooling, the temperature of water can actually drop below 0°C before freezing begins, thus not really offering reliable low-temperature protection via phase change. Water’s powerful phase change is not actually being used when it comes to the refrigerated water PCM, but rather it is being used as a thermal ballast (thermal mass) to just slow down the cooling of refrigerated product. However, since it takes a relatively small amount of energy to cool down refrigerated water while in its liquid range (specific heat, compared to latent heat), it is extremely inefficient to protect from low temperatures using water.

For this reason, large quantities of water, and other buffer materials (e.g., corrugated and/or insulation spacers), are often needed to try to slow down the cooling of product. In addition, refrigerated water is not always placed completely surrounding the payload, which means that external temperatures could also lower product temperatures in areas where refrigerated water is not covering, or close to, the product.
Alternatives on the market today

Shippers today have to balance existing capabilities and operational processes with total cost of ownership and recycle-ability/reuse. This is where new technologies and better insulation material can work together to solve these challenges.

The use of newer PCM technology can significantly reduce the size and weight of thermal storage components, however they too need to be evaluated for cost, custom-ability and other factors. Below are a few alternatives:

Vacuum Panels (VIPs)
In cases where a closed-loop system is in place, vacuum panels (VIP) are a very attractive component due to their excellent insulating properties. Generally speaking, however, they are more expensive than traditional PCMs. They are also fragile, which may require redesigning shipping systems or require adding impact monitoring devices to compensate). Damaged vacuum panels can lose their seal and therefore, their effectiveness.

Flexible Packaging 2-8°C PCM
This method of flexible PCM is similar to a durable bubble wrap, filled with 2-8°C PCM substance rather than air. It uses thin films, equipment is available which can easily change the width, length, weight of the overall component, and weight of the individual pockets of PCM. can improve coverage to all six sides of a payload due to it's flexibility. Therefore, 2-8°C PCM packaged in a thin, light, cost-effective format that evenly distributes PCM around a payload is an excellent option. The main negative feature for a solid to solid material is that phase changes are typically very slow and have a rather low heat of transformation.

Solid to liquid PCMs
Solid–liquid PCMs have the characteristic that their temperature rises as they absorb heat, but unlike conventional sensible heat storage materials (SHS), when PCMs reach the temperature at which they change phase (their melting temperature) they absorb large amounts of heat at an almost constant temperature. The PCM continues to absorb heat without a significant rise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. They also store 5 to 14 times more heat per unit volume than conventional storage materials, like water.
These PCMs also come in many configurations and with different characteristics. Organic PCMs, for example, can be made of Paraffin or fatty acids. Inorganic PCMs include salt hydrates, eutectics are hybrid organic and inorganic chemicals, and lastly there are Hygroscopic materials that can absorb and release water as they give off or absorb heat.

**What type and how much PCM is best for your application?**

1. **Choose a temperature characteristic** - Typically by knowing the safe product temperature range, and taking an average of the two temperatures, you can determine what the PCM temperature is that is needed for your product. If you have only one limit to your temperature range, then you should choose one that is closest to your limit. You should though, check your performance characteristics and run some tests to make the decision on PCM material versus water.

2. Evaluate your selection criteria based on **characterizing your product**. Evaluate
   - Chemical properties, such as toxicity, degradation rate, and stability
   - Thermodynamic properties, such as melting temperature, thermal conductivity
   - Kinetic properties, such as heat recovery rates and avoidance of supercooling
   - Economic properties, such as cost and availability

3. The amount of PCM necessary is calculated by **heating and cooling loads** of the shippers. Infitrak engineers can run this calculation for you and advise which PCMs to use and in what quantities would work best for you. Infitrak can also conduct testing and packaging studies to qualify the factors most affecting your products and determine the right balance of insulation vs PCM material.

**Need help? Here is what you need to know**

Below is a short list of information you will need to determine the type and how much PCM material is needed:

- Temperature characteristics of your product
- Size of shipping container
- Type and thickness of insulation material
- Expected ambient temperatures and desired storage temperatures
- Temperatures of storage required inside the shipper
- Duration of temperatures necessary (keeping in mind transportation mode, possible
If you’d like help in any of this information, need to conduct a temperature mapping study, or in selecting the right containers to ship your product, contact Infitrak.

About Infitrak

Infitrak insulated shipping containers are part of a comprehensive family of cold chain solutions. Infitrak Inc. is a leading provider of intelligent, web-enabled, wired and wireless environmental monitoring systems to highly regulated industries, including hospitals, health care providers, pharmaceutical companies, 3rd party logistics firms and food companies. Infitrak provides out-of-the-box and customized monitoring solutions to meet ongoing changes in technological, regulatory and customer environments. As well, Infitrak provides a comprehensive array of cold chain services to assist clients in meeting regulatory and compliance requirements, including regulatory and compliance gap analysis, packaging design and validation, temperature mapping, equipment qualification, process validation, and many others.