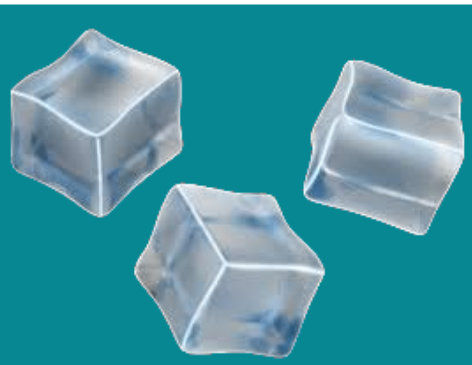
Five questions you must answer to choose the ideal PCM

…and with no chemistry degree required

MesaLabs

www.temptrust.mesalabs.com

> *"Temperature consistency when a PCM oscillates between solid and liquid phases is where a truly good PCM comes in handy. It matches the temperature of the product while it is going through its phase change, making it ideal for temperature sensitive applications."*



Introduction

If you read about phase change materials (PCMs) there is not a lot written to help users select the right kind of PCM to use in a shipment. You can, of course, do a packaging study, or hire a packaging engineer at an ISTA certified lab, but we decided there was a need for a basic, logical set of questions to help in selection...and without knowledge of chemistry or packaging design required. First a disclaimer. This is a tool for reference only and not for scientific purposes. Deviation from a proper temperature packaging study or consulting with a cold chain professional means the risk of losing thousands of dollars in product and R&D time. Now that we have that out of the way, let's see if we can understand the decision making process of choosing a PCM without inducing fear or stress.

What do phase change materials and lava have in common?

Before diving in, let's explain how a PCM works. The best way is via an example we all know, lava. Lava is simply rock that has changed phase from solid to liquid because it has reached its melting temperature. Once it cools, it again takes on its sold-state.

PCMs work the same way. When a PCM (like ice) reaches the temperature at which it changes phase (their melting temperature) they absorb large amounts of heat at an almost constant temperature.

The phase change material will continue heat absorption without a significant increase in temperature until all the material is changed to the liquid phase. If the ambient temperature around a liquid material

Mesa Laboratories, Inc.
3075 14th Ave #1
Markham, ON L3R 5M1
Canada

Phone: 1-905-470-1318
Toll Free: 1-866-421-8367
Fax: 416-767-9790
Email: packaging@mesalabs.com

Liquid, solid, or gas: Temperature consistency is key

decreases, the PCM will solidify, releasing stored, latent heat. Ice to water, water to ice. Rock to lava. Lava to rock.

Temperature consistency when a PCM oscillates between solid and liquid phases is where a truly good PCM comes in handy. It matches the temperature of the product while it is going through its 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

In simplest terms, what you need to know about a PCM is:

1. What **temperature** it takes to change from solid to liquid and back again, and
2. The **heat or cooling it gives off** in the process.

By knowing this, you can match those physical, phase change properties to the temperature stability needs of your product.

Two other things to balance are the **price-to-payload protection factor**, and the **environmental impact** of your solution. It's becoming progressively significant to consider the impact your packaging solution and PCM will have on the environment. Some PCMs leave a negligible carbon footprint, while others may be around for your grandchildren.

Mesa Laboratories, Inc.
3075 14th Ave #1
Markham, ON L3R 5M1
Canada

MesaLabs
www.temptrust.mesalabs.com

Phone: 1-905-470-1318
Toll Free: 1-866-421-8367
Fax: 416-767-9790
Email: packaging@mesalabs.com

Five questions you must answer to choose the right type of PCM

Five decisions you need to make to choose THE IDEAL Type of PCM

When it comes down to it, what do you really need to know when selecting the right type of phase change material for your product? To start with, you'll need to know the answers to these five questions:

If you know the answers to these questions, you can then narrow down the type of PCM you will use.

1	2	3	4	5
What is the acceptable temperature range of the payload needing protection?	What are your required time durations? For example, how long will your product be in transit or storage?	Do you need something easy to use, where complex packaging solutions are not required? If it is fragile, it's not simple.	What are the economics involved in your decision? Think about cost, availability, and reuse.	What environmental impacts should be considered? Focus on non-corrosive, non-toxic, non-flammable & non-explosive.

TABLE 1: FIVE QUESTIONS YOU MUST ANSWER TO CHOOSE AN IDEAL PCM

Mesa Laboratories, Inc.
3075 14th Ave #1
Markham, ON L3R 5M1
Canada

www.temptrust.mesalabs.com

Phone: 1-905-470-1318
Toll Free: 1-866-421-8367
Fax: 416-767-9790
Email: packaging@mesalabs.com

Breaking down the scientific stuff. The highs and the smalls.

At this point, I am going to take a break to mention that there are literally hundreds of types of PCM solutions out there. I mean, face it, and based on the example above, even lava could be a PCM if you were shipping mini volcanoes. Obviously though getting to your ideal solution comes down to a bit of science about thermodynamics, kinetic and chemical properties.

To make it a little easier, I have broken it down into something I am going to call “The highs and the smalls”. Basically you want a PCM with a:

High

- Specific heat
- Latent heat of fusion per unit volume
- Density & thermal conductivity
- Nucleation rate
- Rate of crystal growth

Small

- Vapor pressure at operating temps (reduces containment problems)
- Volume changes on phase transformation
- (Preferably no) degradation after a large number of freeze/melt cycles

TABLE 2: THE HIGHS AND SMALLS. CHEMICAL CHARACTERISTICS THAT ARE IMPORTANT FOR PCMS

Another disclaimer: Although this is brief explanation and seems fairly simple, you should contact a specialist to help you get the most out of your packaging. If you do know what all of these terms mean, you probably don’t need this white paper anyway.

Organics Vs Inorganics: You be the judge

Aside from the scientific terms mentioned above, it should be noted that there are several commonly used phase-change materials within the shipping industry that have been tested to meet the above thermodynamic, kinetic, chemical properties and economic properties you need. Each comes with its own benefits and drawbacks.

Characteristics	Organic Paraffin & fatty acids	Inorganic Salt hydrates
Melt congruently	X	
Availability & low cost	X[1]	X
Change of volume	Low	High
Chemically stable	X	
Compatibility with conventional material of construction	X	
Flammable		X[2]
Freeze without much super cooling	X	Big problem in solid–liquid transition
High heat of fusion	X	X
Thermal conductivity in solid state.	Low[3]	High
No segregation	X	
Recyclable	X	
Safe and non-reactive	X	
Self-nucleating properties	X	Nucleating agents needed, usually inoperative after repeated cycling
Sharp melting point		X
Low volumetric latent heat storage capacity		X

TABLE 3: ORGANIC VERSUS INORGANIC PCMS

Table 3 breaks down the most commonly used PCMs on the market today, organic PCMs (which includes paraffins and fatty acids) and inorganic (which includes salt hydrates).

(1) To obtain reliable phase change points, technical grade paraffin is used, raising costs
(2) Partially alleviated by specialist containment
(3) High heat transfer rates required during freezing cycles

Mesa Laboratories, Inc.
3075 14th Ave #1
Markham, ON L3R 5M1
Canada

MesaLabs
www.temptrust.mesalabs.com

Phone: 1-905-470-1318
Toll Free: 1-866-421-8367
Fax: 416-767-9790
Email: packaging@mesalabs.com

Five questions you must answer to choose the right type of PCM

Narrowing down your selection based on characteristics

Let's go back to the five questions in (Table 1). Assuming you know some of the answers, let's talk about the advantages and disadvantages of each type of PCM. We have a created a simple tool to help you with your decision or you can use the table below for reference:

Characteristics	Advantages	Disadvantages	When to use
Water-based (ice)	• Lowest cost • Non-toxic • Reusable • Good performance • Non-flammable • Easy to use	• Melts quickly • Inconsistent temperature control • Long conditioning time	Chilled, non-critical product handling with low cost & less risky products. Useful to maintain surrounding temperature or thermal load at 0°C. Otherwise, not a viable option.
Paraffin-based (aka n-paraffins, pure paraffins, Petroleum-based PCMs)	• Good thermal storage capacity • Freeze without super cooling • Chemically stabile over multiple cycles • High heat of fusion • Non-corrosive • Compatible & non-reactive w/ most encapsulation materials	• High latent heats • Price fluctuates w/crude oil (cost-effective mixed w/alkanes) • No sharp, well-defined melting points (& limited range of them) • Most are toxic, difficult disposal • Geopolitical consequences • Increase carbon emissions	Closed loop shipping cycles where the product is returning (I.e. human cell–infused medical device in transit)
Salt Hydrates (Eutectic Salts)	• Lowest cost PCM behind water & gel packs • High latent heat values • Non-flammable • Readily available	• Limited temperature ranges • Melts incongruently • Salt settles, collects in container • Poor nucleating properties, nucleating agent required • Volume change, may require special packaging • Corrosive, cannot be microencapsulated • Toxicity (tough to dispose) • Can cause customs issues	Expensive wines and food products, and biological, medical, and pharmaceutical applications
Dry ice (frozen CO2)	• Inexpensive • Readily available	• Not reusable • Requires careful packing	Deep frozen payloads traveling short distances
Vegetable oil-based	• Stable price • In most temp ranges • Temp maintained for extended durations • Long term chemical stability • Biodegradable & non-toxic • No thermal degradation • Can be microencapsulated	New-to-market (untested)	Broad applications: - 90°C to 150°C with latent heats between 150 and 220 J/g.

TABLE 4: ADVANTAGES & DISADVANTAGES OF DIFFERENT TYPES OF PCMS

In packaging, size does matter

Assuming you now know the answer to the five questions, you now need to design a packaging container and determine the amount of PCM to use.

The amount of refrigerant needed is calculated by the heating and cooling loads of the containers. Mesa Labs engineers can run this calculation for you and advise which PCMs to use and in what quantities would work best. The company can also conduct testing and packaging studies to qualify the factors most affecting your products and determine the right balance of insulation versus refrigerant.

About Mesa Labs

Mesa Labs, formerly Infitrak, is a leader in providing of cold chain packaging solutions and related cold chain packaging services, for the life sciences market. The Mesa Labs packaging line, called TempTrust, helps clients to assure their pharmaceuticals, blood, tissue, and other products remain in compliance with regulatory guidelines and are stored or transported under ideal conditions. In conjunction with our ISTA Certified Lab, TempTrust cold chain packaging reduces cost and weight, and is designed to surpass existing compliance standards. For more information about TempTrust packaging, PCMs or related services, visit us at www.temptrust.mesalabs.com

Sources

- http://www.pharmoutsourcing.com/Featured-Articles/37644-Upgrading-of-Traditional-Cold-Chain-Shipping-Systems-Using-2-8-C-Phase-Change-Materials/ , Upgrading of Traditional Cold Chain Shipping Systems Using 2-8°C Phase Change Materials posted Jan 1, 2012
- Verner, C. Phase Change Thermal Energy Storage. Thesis, Brighton University (Seehttp://freespace.virgin. net/m.eckert/ carl_vener's_dissertation.htm), May, 1997.
- Lane.G.A. "Phase Change Material for Energy Storage Nucleation to Prevent Supercooling," Solar Energy Materials and Solar Cells 27 135-160, p4, 1991.
- National Science Foundation, SBIR, Award Number - 0750470 1
- United States Department of Agriculture, SBIR, Project Number MOK-2003-05519
- United States Department of Agriculture, NRI, Project Number MOR-2005-02692
- Internal Studies Conducted by Phase Change Energy Solutions-2009, Entropy Solutions Inc-2009, University of Missouri-Columbia -2007.
- Abhat, A. "Low Temperature Latent Heat Thermal Energy Storage: Heat Storage Materials," Solar Energy, Vol. 30, No. 4, 313-332, 1983.

Mesa Laboratories, Inc.
3075 14th Ave #1
Markham, ON L3R 5M1
Canada

www.temptrust.mesalabs.com

Phone: 1-905-470-1318
Toll Free: 1-866-421-8367
Fax: 416-767-9790
Email: packaging@mesalabs.com