INTELSIUS WHITE PAPER
HOW PCM WORKS

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WHAT IS PCM?

Temperature controlled packaging (TCP) has been around for a while, helping shipments of temperature sensitive products make their way around the world and protecting product integrity. TCP is able to stabilise the temperature of products by utilising phase change material (PCM). This article will discuss how PCM works so you can understand how best to prepare it and why careful preparation is important for successful shipments whatever the requirement.

Think of PCM as a rechargeable battery but instead of holding electrical energy, it can store and release large amounts of thermal energy (aka heat). When fully frozen the PCM is 100% charged; as the PCM melts the charge reduces, reaching 0% when fully melted. During this process the PCM changes phase from solid to liquid. The temperature a PCM changes phase at is called the phase change temperature (PCT) and is dependent on the molecules and bonds it contains, which differs for each type of PCM. The PCT is vital in understanding how to prepare and use a PCM. This will be explained in further detail later.

HOW PCM WORKS?

The most commonly used and well-known example of PCM is water. We've all used ice to keep a drink cool or ice packs in a cool box to keep a picnic fresh. This is the same scenario that taking place in TCP. The ice absorbs excess thermal energy, breaking bonds, allowing the ice to melt, and protecting your picnic from absorbing the thermal energy itself. Now imagine you're holding a lump of ice in your hand. It's cold, 0°C to be exact. We know this because this is the PCT for ice changing to water. As it melts the lump of ice will get smaller but the temperature remains the same. You'll have to wait until the ice is completely melted before your hand will warm up. Again, this is what happens in your cool box: the temperature within will remain relatively steady while there is still ice left in the ice packs. Once the ice is fully melted, there is nothing left but the food to absorb excess thermal energy, meaning the temperature will now begin to increase.

PCM can also be used to keep a product warm using the same process as described for ice but in reverse, starting with the PCM in its liquid phase. In this case the PCM will release thermal energy to the product and its surroundings, forming bonds and freezing as it goes, protecting the product from losing thermal energy by supplying it with heat.

CHOOSING THE RIGHT PCM

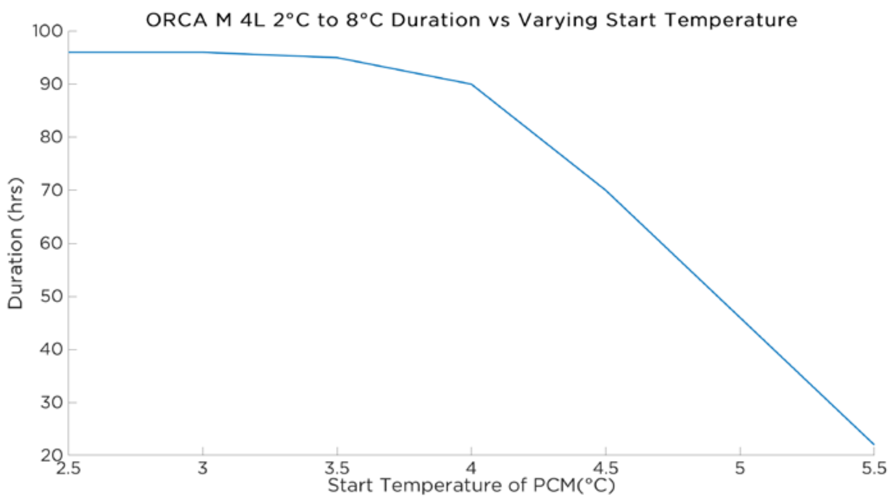
To choose the right PCM you need to know the temperature range you want your products to remain within. As discussed above, PCM holds a certain temperature as it's changing phase. This means you want a PCM with a PCT slap bang in the middle of the required temperature range for the best results. For example, 2-8°C is a popular temperature range for cold chain shipments. At Intelsius we use a PCM called Plantol with a PCT of 4.9°C. This will help hold the temperature within our TCP between 2°C and 8°C until all of the Plantol has melted. In many cases ice is used but as it has a PCT of 0°C, there is a risk of cold shocking the product.

Cold shocking is when a payload temperature drops below the lower temperature boundary, specifically due to the PCM (in this case ice) being too cold and not due to cold external temperatures. To avoid this, protection can be added to prevent the ice and product from touching, typically expanded polystyrene (EPS) spacers or water bags are used but these increase the size and weight of the TCP, in turn increasing cost. Therefore PCM is the safest and most stable option.

PREPARING THE PCM - TESTING

Once you've chosen the correct PCM for your product, understanding how to prepare it for a shipment is the next step. To achieve the best possible performance it is vital that the PCM is conditioned correctly, ensuring 100% charge. The temperature of the PCM when packed is known as the start temperature. If the PCM is to be used when frozen, the start temperature should be slightly lower than the PCT when packed. If the PCM is to be used when liquid, the start temperature should be slightly higher. To explain this further and demonstrate the consequences of incorrect preparation, a test was carried out at Intelsius using ATMOS Packaging, a platform that enables the user to simulate shipments and gain results much faster than in physical testing.

For the test we used one of our vacuum insulation panel (VIP) systems, the ORCA M 4L 2°C to 8°C, with a payload of six 10ml test tubes filled with water. The PCM used in this system is Plantol which, as previously mentioned, has a PCT of 4.9°C. In thermal qualification testing this system maintained an internal temperature between 2-8°C for 97 hours and 10 minutes with a start temperature of 3°C for Plantol. To see how the start temperature affected the duration, the ORCA M 4L 2°C to 8°C was tested multiple times against the ISTA 7D Summer profile with the start temperature of Plantol increasing from 2.5°C to 5.5°C in 0.5°C increments. The results are shown in the graph below.

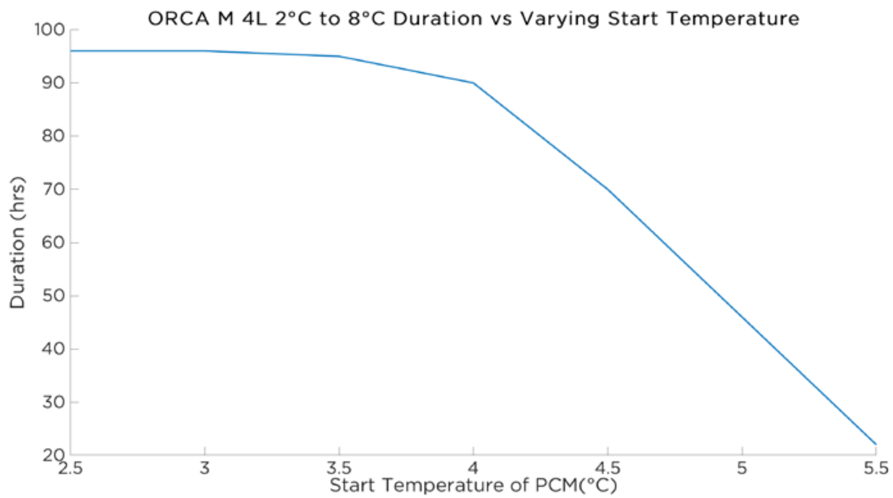


PREPARING THE PCM - ANALYSIS

The graph shows that for start temperatures between 2.5°C and 4°C there is little difference in duration, seen by the relatively flat gradient. This is because the PCM has, or is close to, 100% charge at these temperatures so maximum duration is achieved. Although start temperatures below the lower temperature boundary of 2°C would give a similar duration, it would put the payload at risk of cold shock.

At temperatures over 4°C you will notice on the graph a steep, negative gradient. This demonstrates how duration significantly decreases as the PCT is approached. A loss of around 20 hours is seen by increasing the start temperature from 4°C to 4.5°C. Although this is below the PCT, the molecules at the surface of Plantol are susceptible to melting. This can be related to a freshly made cup of tea: you can see steam rising from it as it sits on your desk but the water is not at its boiling point of 100°C. The steam is produced by surface water molecules gaining enough energy to break bonds with other water molecules and changing phase from liquid to gas. The same is happening with Plantol, except the phase change is from solid to liquid.

As the start temperature nears and exceeds the PCT, the percentage of PCM that has melted increases, reducing its ability to absorb heat, and so the duration drops further still. Eventually, at high enough temperatures, the PCM will be completely melted and the packaging will not hold the desired temperature at all.



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CONCLUSION

In conclusion, the results show that the ORCA M 4L system will perform best when Plantol has a start temperature at least 1°C below its PCT. This can be applied to other PCMs, including water, that are to be used when frozen. This will make sure that the PCM is 100% charged when the systems are packed and there is no loss of performance. Similarly, if a PCM is to be used when liquid, it should be conditioned at least 1°C above its PCT to reach maximum duration. However, be sure not to condition PCM too close to the upper and lower temperature boundaries of the payload. This could lead to a system failing for being out of specification as soon as it's packed.

Now you know how PCM works and why correct conditioning and preparation is so important for achieving optimum performance. To aid Intelsius customers, detailed instructions on conditioning and assembly of our TCP products are available, ensuring your packaging performs at its best.

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