Serious About Tarmac Time –

Comparison of Different Approaches for Increased Thermal Protection and New Solutions for Low-mass Pallets of Pharmaceutical Goods

Temperature excursions during loading and unloading procedures of air-freight shipments (so called 'tarmac times') of pharmaceutical products represent a major challenge for a fully controlled cool chain.

While pharmaceutical products in the 2-8°C temperature range are usually being transported in more expensive passive or active shipping containers, products in the so-called "controlled room temperature" or "ambient temperature" ranges (mostly 15-25°C but also 2-25°, 2-30°C or 2-40°C) are generally protected by more economical packaging solutions for the direct transport interfaces, i.e. the tarmac times during airport ground handling situations. The standard solution in the industry for this solution is thermal blankets. Currently, a wide range of blanket types coexists on the market, ranging from reflective bubble wrap, over thin reflective covers from nonwoven fabric to thicker, multilayer wrapping solutions. Basically, all of these blanket types aim at providing protection from:

- Heat spikes through solar radiation
- Heat spikes through hot ambient temperatures
- Cold spikes through cold ambient temperatures.

While the use of standard thermal blankets does indeed provide adequate protection for most shipments temperature excursions can occasionally still result from a combination of the following three adverse factors:

Very hot or cold ambient temperatures
- Longer than average tarmac times
- Low thermal mass of products.

The third factor in particular is often overlooked when determining the performance of a given thermal blanket solution.Why thermal mass is so important is easy to understand by comparing the amount of energy required to heat one litre of water and one litre of air for an increment of one degree Kelvin.. Whereas the former requires 4183 Joules, the latter only requires 1.036 Joule , i.e. just 0.03% of the energy required to heat the same volume of water for the same increment. Since standard thermal blankets, unlike passive shipper boxes, do not add any thermal mass, palletised goods of low mass are inherently more susceptible to temperature excursion than pallets of higher mass.

To illustrate the difference between thermal blankets of different thickness but similar materials (bubble wrap, coated with aluminum foil on both sides), we performed comparative climate chamber tests. Our company's standard solution, ECO-SAFE (7mm thickness), was compared with two blankets of 16 and 32mm overall thickness. The test was performed on a EUR pallet of 120cm net height. A total of 16 empty corrugated cardboard boxes with dimensions of 600x400x300mm acted as (worst case) dummy load. A total of 10 dataloggers was distributed symmetrically in the pallets. While the measured temperatures between different logger positions varied slightly, it was irrelevant which logger position is taken to compare different solutions. In the following, the centre logger of each test run is chosen, with the results shown in Figure 1.

As can be seen, all thermal blankets significantly slow down the process of temperature equilibration between the ambient temperature and the temperature measured inside the protected pallet with zero mass dummy load. However, the difference in temperature protection between the different covers is only small. Measured by the following thermal

$$TP = 1 - \frac{(T_{max} - T_{min})\ protected}{(T_{max} - T_{min})\ unprotected}$$

protection metric where TP is a metric which measures the reduced thermal stress in per cent (a value of 1 denotes total protection, i.e. no change in temperature underneath the blankets, whereas a value of 0

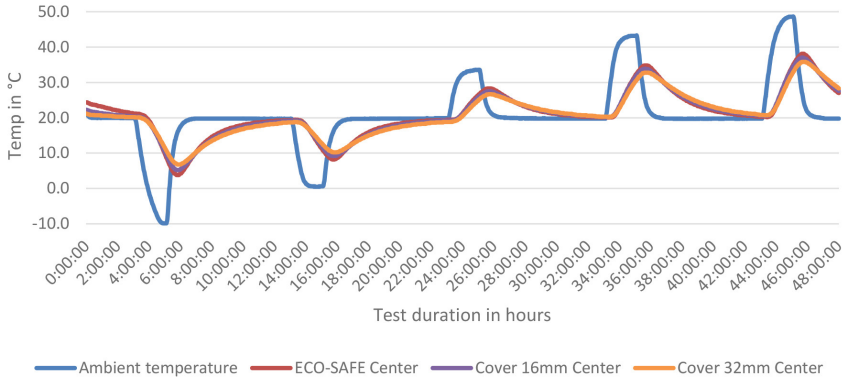


Figure 1: Results of climate chamber tests.

Measurement	Min	Max	Amplitude	Thermal protection
Ambient temp	-9.9°C	48.7°C	58.6°C	N.A.
ECO-SAFE	3.8°C	38.1°C	34.3°C	41%
Thermocover 16mm	5.2°C	37.0°C	31.8°C	46%
Thermocover 32mm	6.8°C	35.8°C	29.0°C	51%

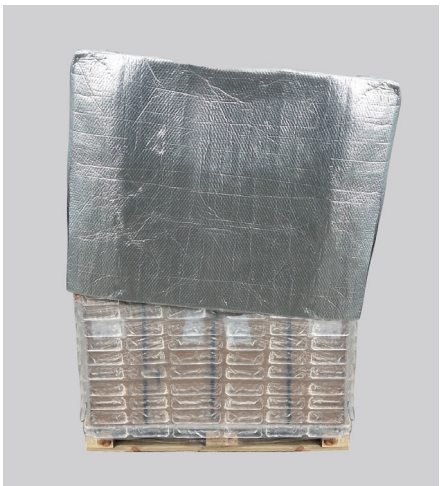
Table 1: Numeric summary of climate chamber test

would denote no protective value at all). Table 1 lists the numeric results from the test.

The results imply that doubling the thickness of the thermal blanket yields a five percentage point increase in thermal protection. Even though this difference is measurable, it is questionable if it justifies the associated additional costs (price of thicker blankets, additional required storage space and potentially higher freight costs due to bulkier pallet dimensions) of choosing a thicker thermal blanket.

Our answer to the challenge of providing increased thermal protection for low-mass pallets of pharmaceutical goods is the innovative ECO-SAFE+ solution. It consists of five to six so-called Water-Blankets (depending on pallet base format) and a standard ECO-SAFE thermal blanket.

Picture 1: Five Water-Blankets assembled on a EUR-sized pallet



Picture 2: Complete ECO-SAFE+ solution (for clarification, only partly pulled down)

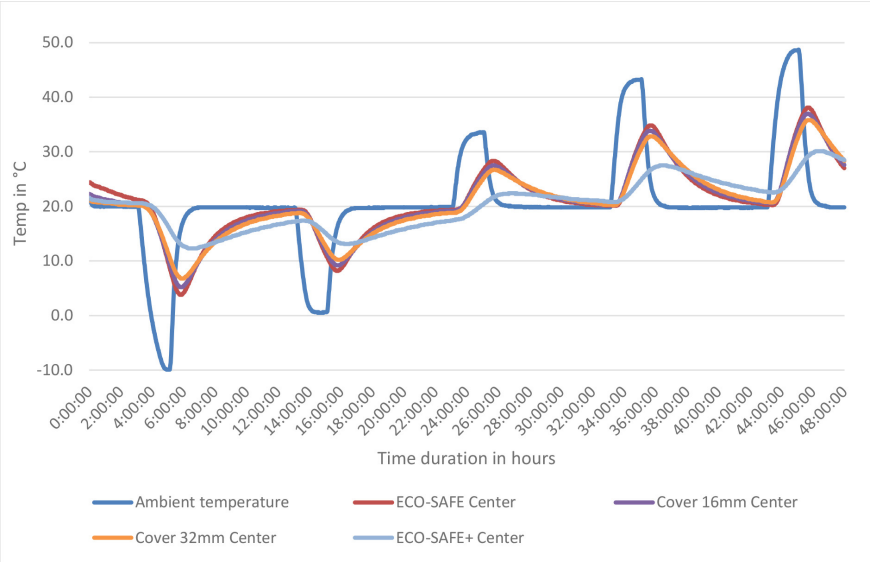


Figure 2: Climate chamber test including ECO-SAFE+

Water-Blankets are sleeves of 38cm width and variable length which are intended to bring additional thermal mass to the low-mass pallets with sensitive goods. They consist of small pockets, filled with water-based gel, and can be produced for any pallet heights. The gel consists of 99.5% water and 0.5% polyacrylate. It is harmless and also used in Coolpacks for the shipment of fresh foods or chilled pharmaceuticals. Unlike traditional cooling elements, Water-Blankets offer the advantage of applying thermal mass to all sides of the pallet and not just to the top. The foil used for the production of Water-Blankets is very pressureresistant, so that pallets wrapped with Water-Blankets remain stackable. For a EUR-pallet with height of 120cm, the Water-Blankets would add around 33kg of thermal mass, without adding additional chargeable volume. This is a main advantage of the ECO-SAFE+ solution, compared to other, more voluminous packaging options, since typically, volumetric weight determines the freight costs.

Since Water-Blankets do not have to be preconditioned in any particular way, the whole operational procedure of assembling a pallet with the ECO-SAFE+ solution does not take more than five minutes on average.

In order to assess the thermal protection achieved by the ECO-SAFE+ solution, the climate chamber test described in Figure 1 and Table 1 is repeated, this timeincluding the ECO-SAFE+ solution.

The advantages of the ECO-SAFE+ solution are directly visible from Figure 2. Compared to the three standard blankets shown before, the temperatures in a pallet protected by five standard Water-Blankets and an ECO-SAFE thermal blanket show significant smaller fluctuations. The minimum temperature during an ambient temperature of -10°C remains above +10°C, whereas the maximum temperature measured during +50°C ambient temperature is just above +30°C. This visual impression is fully confirmed by the summary statistics (see Table 2).

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ECO-SAFE	3.8°C	38.1°C	34.3°C	41%
Thermocover 16mm	5.2°C	37.0°C	31.8°C	46%
Thermocover 32mm	6.8°C	35.8°C	29.0°C	51%
ECO-SAFE+	12.3°C	30.1°C	22.1°C	70%

Table 2: Numeric summary of climate chamber test including ECO-SAFE+

The thermal protection metric for ECO-SAFE+ reaches 70% compared to values between 41% and 51% for the standard thermal blankets without the additional Water-Blankets. This result confirms the theoretical consideration, that additional thermal mass combined with a standard thermal blanket might outperform very bulky, multilayer blankets in terms of thermal protection.

For even better thermal performance, we offer the Water-Blankets in conjunction with a six-piece collapsible pallet shipper, made from EPS side walls, covered with reflective insulation foil (ECO-SAFE++). Even though this solution is suited to fully sustain the important 15-25°C temperature range under most shipping situations, specific customer requirements have led us to produce the ECO-SAFE++ shipper with PCM blankets. By making use of the latent heat stored by specific PCM fluids, even better temperature control can be assured for very specific temperature ranges under most testing ambient conditions.

Picture 4: ECO-SAFE++ shipper (fully assembled)

Picture 3: ECO-SAFE++ shipper (partly assembled)

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The general manager of ECOCOOL GmbH, located in Bremerhaven, Germany. Dr Florian Siedenburg graduated in 2006 in Economics and obtained his doctoral degree in Econometrics in 2010. He entered the family-owned business in 2013. ECOCOOL GmbH was founded in 1999. ECOCOOL specialises in the development and distribution of insulating packaging. As of today, thermal blankets and other passive packaging for pharmaceutical air-freight constitute the core business of ECOCOOL.

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