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PERFORMANCE CURVES

Footprint of the thermal performance of passive shippers

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In temperature-controlled logistics, a wide range of passive shipper systems is available from various vendors, designed to keep temperature-sensitive payloads within a designated temperature range during transportation along a distribution lane. It is challenging to predict how a shipper will perform on a given lane and pick out the best-performing shipper. The performance curve is a tool to help in that decision. It can be used to compare the thermal performance of passive shipper systems, and thus identify which shipper systems are potentially adequate for a specific lane. This will reduce the number of time-consuming detailed risk analyses to a limited selection of shippers.

1 Why using performance curves

In temperature-controlled logistics, passive shipper systems are used as cost-effective transport solutions to keep a temperature-sensitive payload within a designated temperature range. Since each shipping lane has a different temperature profile, and even a single lane has a different temperature profile at different times (summer/winter, day/night), it has to be decided on a case-to-case basis which shipper is suited for which lane. The performance curve provides a footprint of the thermal performance of a shipper, which can assist in choosing the right shipper for a lane.

It has been common practice to use standard temperature reference profiles to qualify a shipper. For example, shippers are often tested against the commonly known reference temperature profile ISTA-7D. Such reference profiles are helpful to generally compare the performance of shippers. But the limitation of such reference qualifications is that many shippers are compliant with such references. So, if all shippers meet the reference criteria, it is not useful for deciding which shipper to take for a specific lane. Also, since reference profiles are per se generic and not lane specific, it remains unclear how a shipper that is qualified against a reference profile, will perform on a realistic lane.

The performance curve provides more information about the thermal performance of a shipper, and makes it easier to compare the expected performance of different shippers under lane conditions. This makes the performance curves very useful, because it helps to limit the number of shippers that have the potential to meet the criteria of a given lane. Detailed time-consuming risk analysis can then be carried out on the reduced preselection of shippers, and need not be done on all available ones.

2 Definition of performance curve

The performance curve, sometimes also referred to as sweet spot curve, is based on an idea initially proposed by McGarvey et al. [1]. It represents the lifetime of a payload in a specific passive shipper system as function of ambient temperature. A typical performance curve for an exemplary shipper with a 2-8°C payload is shown in Figure 1. It can be seen from the curve that when the exemplary shipper, including payload, is exposed to a constant temperature of 24°C, the payload lifetime is 62.25 hours.

It is important to note that a performance curve always represents the performance of one particular shipper layout in combination with one particular payload. If the same shipper was used for two different payloads (of differing thermal masses), their performance curves would be different. Similarly, even if shipper layout and payload are the same, but the initial temperature of cool packs is varied, for example from -5°C in one case to -10°C in another, the performance curves for these two cases are different.

Typically, each shipper has a performance optimum at some ambient temperature range. This temperature range is commonly referred to as “sweet spot”. For the shipper in Figure 1, the sweet spot is indicated by the blue ambient temperature range between 7 and 19°C, where the payload lifetime is more than 100 hours (capped at 100 hours in figure).

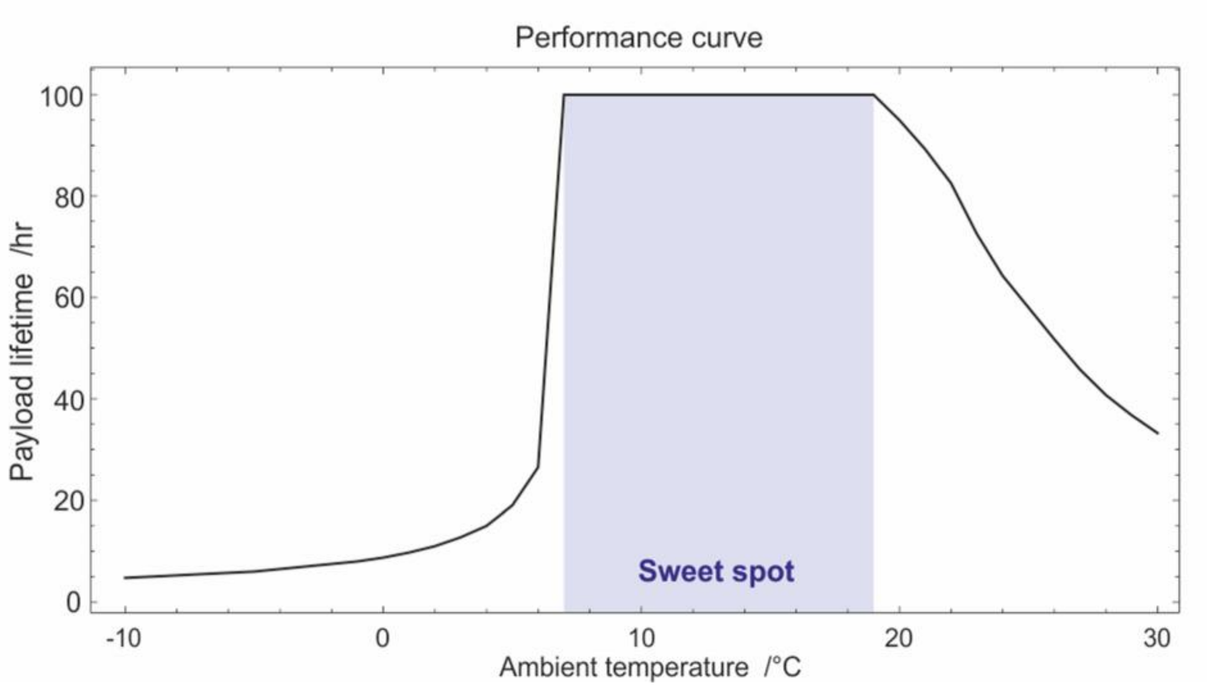

Figure 1: The performance curve represents the lifetime of a temperature-sensitive payload for a shipper as function of ambient temperature. Maximum lifetime is capped at 100 hours. Solid black line – performance curve; blue area – “sweet spot”, i.e. ambient temperature range where shipper performance is optimal.

The performance curve provides a footprint of the thermal performance of a shipper. For the example shown in Figure 1 it can be seen that the shipper is not well suited for cold lanes, where temperatures of less than 6°C can occur. Here, the performance curve indicates a payload lifetime of less than 20 hours. Steep gradients in the performance curve indicate that the shipper is very sensitive to temperature changes. For the example in Figure 1, the shipper performs well at 8°C where the lifetime is more than 100 hours, whereas at 6°C the lifetime is only about 25 hours. This means there is not much of a tolerance at these temperatures.

The performance curve is created either experimentally or by simulation. The experimental time required to generate a performance curve is the sum of all payload lifetimes, plus additional handling time in a cold chamber to prepare and equilibrate the shipper. The example in Figure 1 would have required 3 months cold chamber time, neglecting any additional handling times. Using simulation tools like SmartCAE Performance Curve, the performance curve is generated within a matter of minutes.

3 Using a performance curve to estimate shipper performance

The performance curve can be used to estimate the performance of a shipper on a lane. This is an advantage compared to using reference profiles, because it is generally not possible to transfer the thermal performance on a reference profile to a realistic temperature profile on a lane. Here we look at how the shipper with the performance curve shown in Figure 1 would perform in three scenarios.

3.1 Scenario “mild lane”

In the “mild lane” scenario, a shipper is required for a short lane time with mild temperatures, for example for the lane from Munich to Hamburg in May. The lane temperature is expected to be within 10 and 25°C, the lane time is 12 hours. The performance curve analysis is shown in Figure 2. Since minimum and maximum expected lane temperatures are well included in the performance curve, the shipper is well suited for this lane.

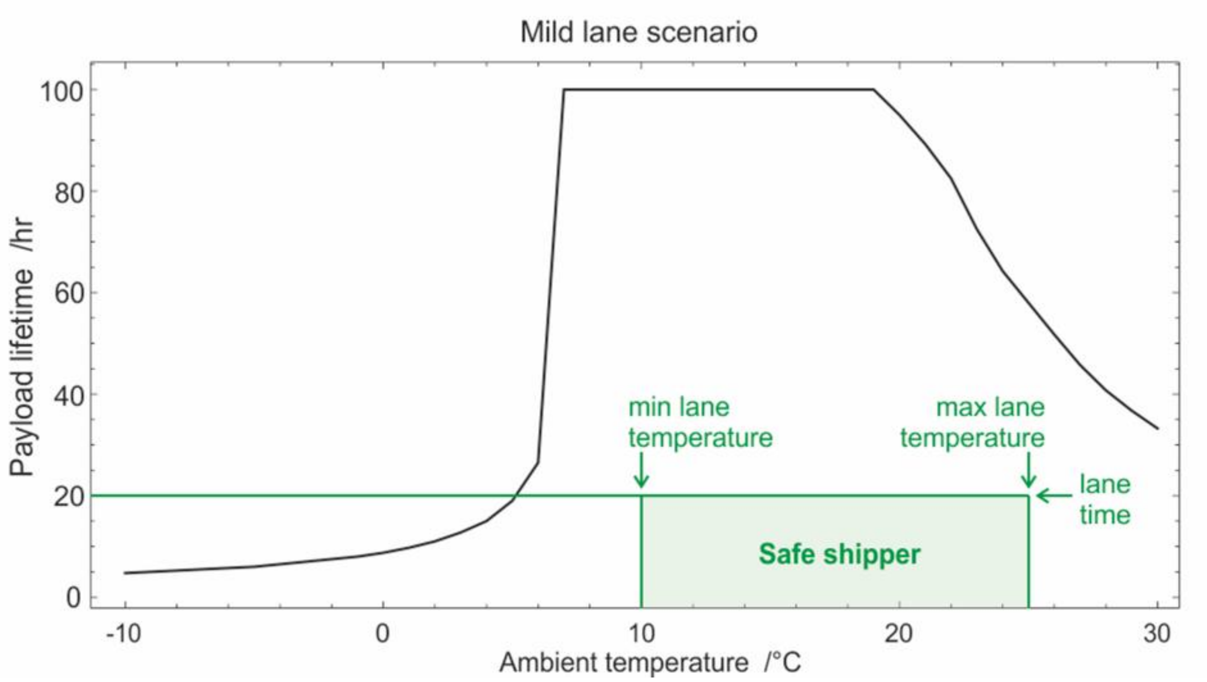

Figure 2: Lane temperature is within performance curve for the entire lane time, indicating that the shipper is a safe choice for this lane. Black line – performance curve; green lines – lane characteristics.

3.2 Scenario “cold lane”

In this scenario, a shipper needs to be used for a lane during winter with cold temperatures, for example from Berlin to Moscow in February. The temperature on the lane is expected to vary between -10°C and +5°C, the total lane time is 52 hours. Figure 3 shows the performance curve analysis. The expected lane temperatures significantly exceed the performance curve, indicating that the shipper is not a good choice for this lane. There is a high risk for shipper failure, due to the payload dropping below its 2°C lower temperature limit.

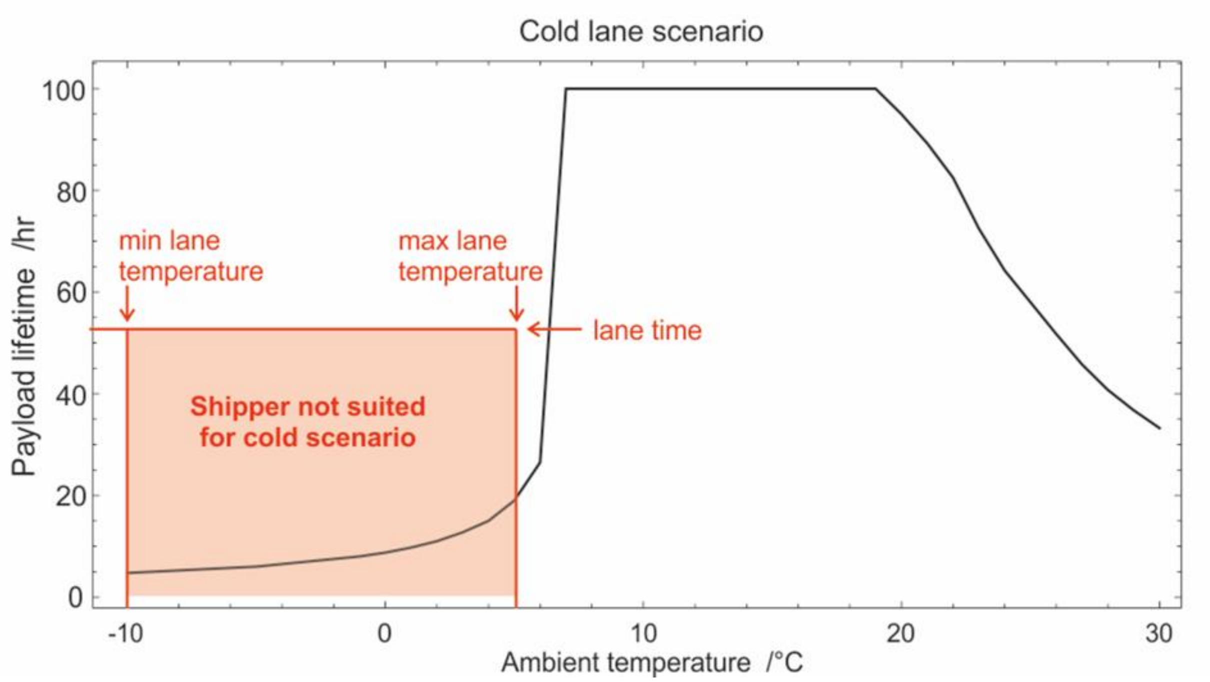

Figure 3: Lane temperature exceeds performance curve for the planned lane time of 52 hours, indicating that shipper is not suited for the "cold lane" scenario. Black line – performance curve; red lines – lane characteristics.

3.3 Scenario "variable lane"

In the "variable lane" scenario, a broad range of ambient temperatures is encountered on the lane, so that there is a wide spread between the minimum and maximum lane temperature. In the performance curve analysis in in Figure 4, the lane temperature spread is wider than the sweet spot of the shipper. In this case, part of the lane temperatures exceed the performance curve, while other parts are within the performance curve. This indicates that the shipper has an elevated failure risk. A more detailed risk analysis would be required to make a solid decision whether this shipper is adequate for the lane.

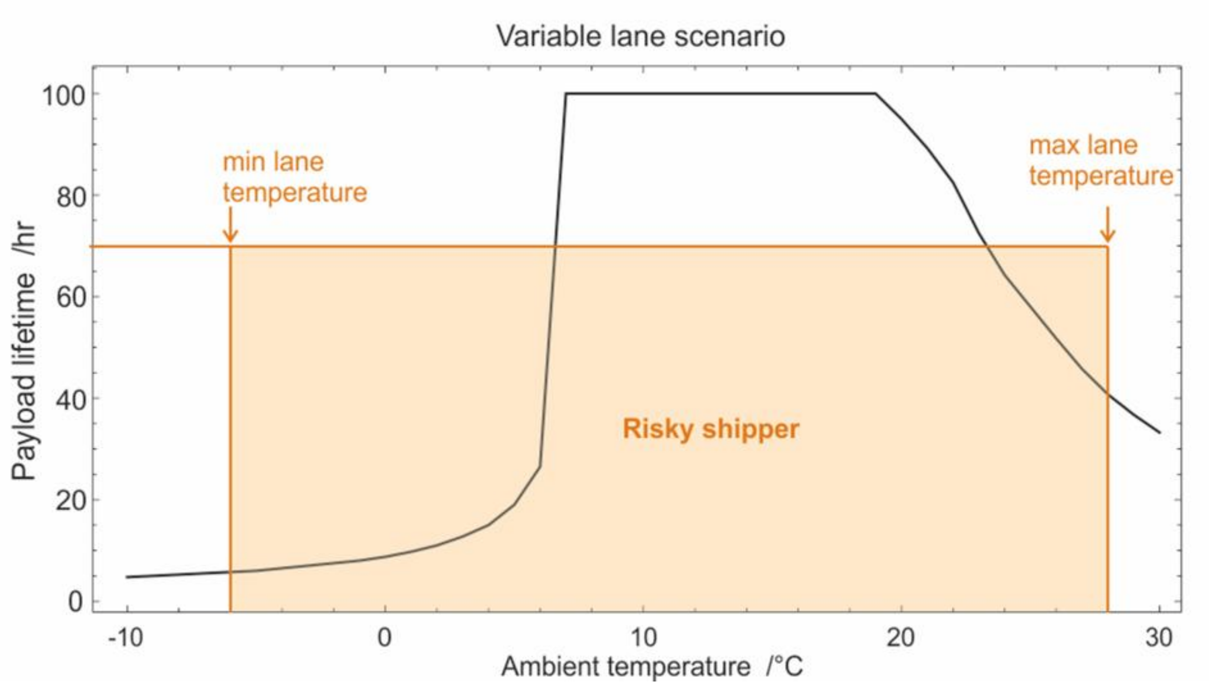

Figure 4: Spread of lane temperatures is significantly wider than sweet spot of performance curve. Shipper is considered risky for this lane. Black line – performance curve; orange lines – lane characteristics.

4 Choosing winter and summer packout

In many practical situations a different shipper packout is used during winter and summer months. The performance curve can be used to determine good candidates with complementing properties to find a good pair of packouts. An example for a good pair is shown in Figure 5: the performance curve of the winter packout (dashed line) and of the summer packout (solid line) complement each other, so that the combined performance curve has a broader sweet spot compared to each individual curve.

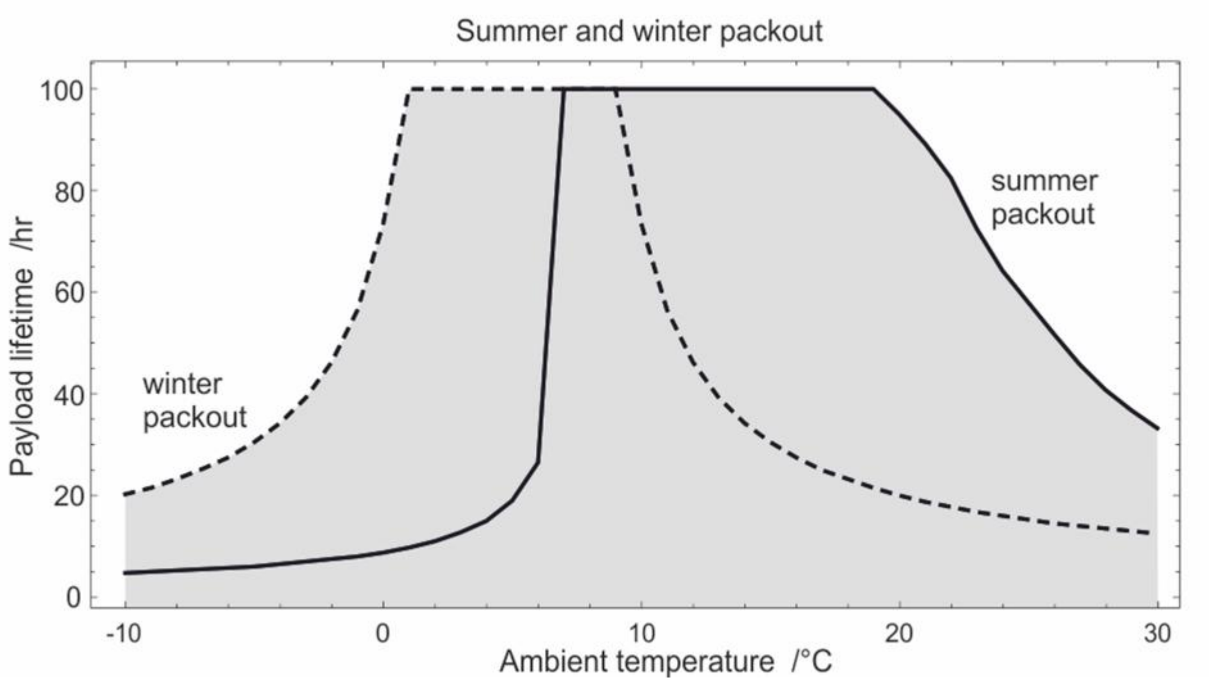

Figure 5: The performance curves of summer and winter packouts complement each other to give an improved combined performance curve, indicating a suitable choice for summer/winter packout combination.

If the performance curves of summer and winter packout do not overlap in their sweet spot, they do not form a favorable shipper combination. An example is shown in Figure 6: the combined sweet spot curve has a gap between 6 and 11°C, indicating an elevated risk at intermediate temperatures.

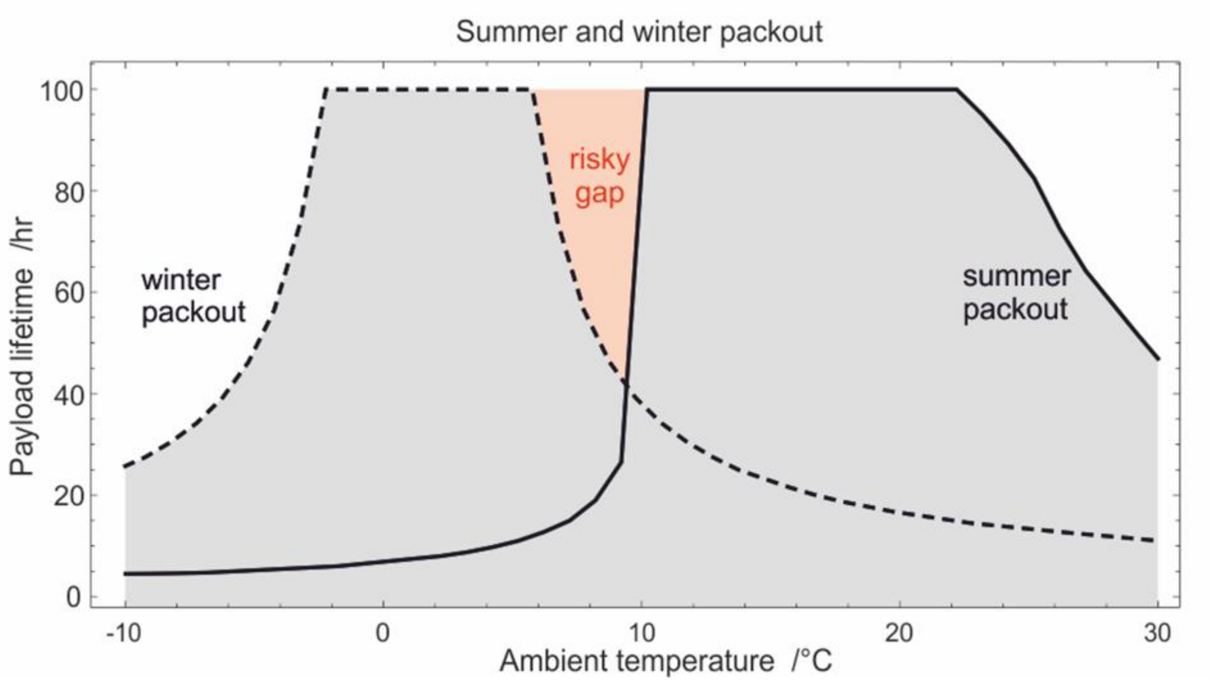

Figure 6: Unfavorable combination of summer and winter packouts with high risk at intermediate ambient temperatures.

5 Conclusion

Passive shipper systems are widely used in temperature-controlled logistics to transport temperature-sensitive products along distribution lanes. The common challenge in these operations is to find the shipper that best matches the thermal requirements demanded by the lane. The performance curve is a practical tool to assess the thermal performance of passive shipper systems, and can be very helpful to guide decisions on choosing an appropriate and cost-effective shipper.

It is relatively time-consuming to generate a performance curve based on lab testing. In particular, since the performance curve characterizes the performance of the combination of shipper and payload, it can be necessary to determine multiple performance curves for a single shipper layout, when the performance for different payloads is of interest. Using simulation tools like SmartCAE Performance Curve, a performance curve can be determined much faster, in a matter of minutes. With the help of simulation the performance curve can be a time and cost-effective standard for characterizing the thermal shipper performance.

6 References

[1] Bernard McGarvey, Eli Lilly and Co.; Geoff Kaiser and Shreyas Panse, Cold Chain Technologies; and Paul Harber, Modality Solutions. http://pharmaceuticalcommerce.com/supply-chain-logistics/a-new-way-to-look-at-the-performance-of-passive-cold-chain-shipping-containers (accessed 08-Feb-2017).

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