Envirocooler® Engineered Polyurethane (ePUR™): 30% higher R-Value and 34% less dense means lower total delivered cost

Overview

Jarden Life Sciences is introducing a new insulation material—Envirocooler® engineered PUR, or ePUR™—to the life sciences packaging market. This material substantially increases insulation performance relative to conventional PURs (which are in turn substantially better insulators than EPS).

Envirocooler® ePUR™ offers a smaller size and weight for equivalent performance—or substantially higher performance with similar dimensions to conventional PUR. These can result in significant reductions in total delivered cost.

Introduction

For transporting temperature-controlled life science products (pharmaceuticals, biologicals and medical devices), there are a bewildering array of design options. Package, parcel or pallet sizes; passive designs with refrigerants or active designs with battery-powered cooling (or heating); insulation materials ranging from plastic foams to vacuum insulated panels to high-tech ceramic materials; and more. Many designs arise from the specific needs of the shipper, bulk or carton-size quantities, short distance shipping lanes or intercontinental ones, and economic tradeoffs between container cost and logistics costs.

Most systems for transporting temperature-sensitive life science materials (drugs, medical devices, vaccines, blood and tissue products, and clinical trial materials) have three basic components: a container to keep everything together, a source of cold, and insulation. The container can be rigid (including metal boxes, paper or fiberboard) or flexible pouches for small, hand-carried deliveries. The source of cold, which allows the shipment to maintain a desired temperature for a specified period of time, can be wet or dry ice, gel packs or a variety of powered refrigerated systems. The insulation is usually expanded polystyrene (EPS), polyurethane (PUR), vacuum insulated panels (VIPs), or a variety of high-tech materials, including nanoceramics and others. (Note: these are listed roughly in order of rising cost.)

Both active (powered) refrigerated systems and passive systems using ice or chilled materials employ insulation—it reduces heat transfer to keep products within the desired temperature ranges, as well as protects the products from physical damage. Some active systems are complex and relatively expensive to use, and therefore tend to be employed for high-value, bulk shipments, or special situations such as the portable units used to carry samples to doctors' offices. Designing the insulation for these is a lesser concern for the overall system, because the designer can specify a wide range of cooling capacities in the refrigerated system.

But the picture is different for passive systems. Here, the choice of insulation materials and their thickness, weight and insulating capability are all critical factors in the overall system design. Designers undertake a sophisticated process of specifying the insulation layer, which can be an integrated box-and-lid, panels or other configurations. Greater thickness provides more insulation value but reduces payload capacity. Weight and dimensions are a factor in shipping costs, especially in situations where logistics providers, such as UPS and FedEx, charge based on "dimensional weight" (DIM weight), or the amount of space a package occupies in relation to its actual weight. Packages that are less dense will have a lower DIM weight and are less expensive to ship than packages with higher DIM weight.

The critical measure: R-value

The key performance factor of insulation materials is R-value, a measure of heat transfer. R-value is defined as a material's resistance to conductive, convective or radiative heat flow through the material (depending on the structure of the material). It is highly dependent on the material's thickness and density and can vary greatly depending on these two factors. The R-value represents a ratio of the temperature difference across a material and the heat transfer per unit area and time through it, given as:

$$R = \frac{\Delta T}{Q_{AREA}}$$

The greater the R-value, the greater the material's insulating ability. Thus, this concept can also be applied to entire systems to determine a cumulative System R-value that aims to quantify the thermal resistance of a system.

The greater the R-value of a system, the more effective it is at maintaining a temperature difference between itself and external systems that it is in contact with.

Here's a rundown of the insulation materials of interest:

Fig.1

	R-value	Density (lb/ft<3>)	Relative Cost	Notes
EPS	3-4	1-5	Low	Molded or cut container shapes; typically not reused
PUR	5-6	3-4	Moderate	Molded container shape; potential reuse
VIP	35-50	N/A	Very High	Reuse critical to economics; yet relatively fragile
Envirocooler® ePUR™	7.8	2-3	Moderate	Molded container shape; potential reuse

Conventional PUR is widely used as an insulation material—it is inside refrigerator doors, for example, and a growing part of building construction, in automobiles (for sound and heat insulation) boats (taking advantage of its buoyancy) and elsewhere a controlled temperature is desired. PUR for pharmaceutical packages is specified primarily for its insulating properties. Insulating PUR materials are produced by reacting two polymers together in the presence of a catalyst to initiate the reaction, and a blowing agent to control the microcellular structure within the foam. (The chemical reaction also produces byproduct gases that aid in creating the microcells, and water can be part of this reaction).

Envirocooler® ePUR™ is a new combination of polymers, catalysts and blowing agents characterized by an improved cellular structure and, thus, better insulating properties.

Envirocooler® ePUR™ can dramatically reshape the performance of insulated packages. Envirocooler® ePUR™ depends, in part, on the chemistry of the reactants; but it also depends on sophisticated forming technology, such as the use of what is known in the industry as "autofrothing" to control the size and density of bubbles in the foam as container panels are cast.

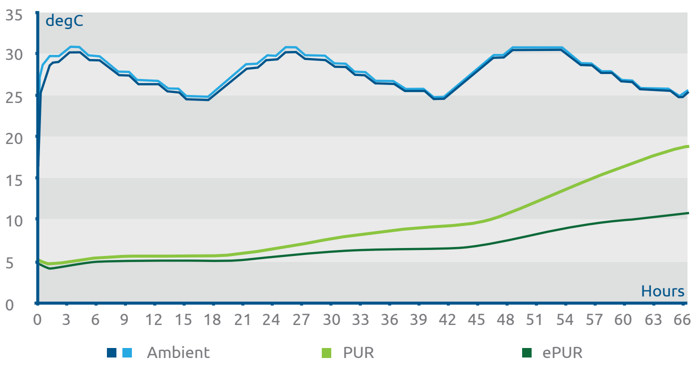
The new PUR formulations are already industry-proven in a number of non-packaging applications, such as appliances or construction materials. Their use in life sciences packaging is being pioneered by Jarden Life Sciences, which has substantial experience in working with PUR and other insulation materials such as EPS, VIPs, gel refrigerants, and active parcel systems, in industry applications.

Envirocooler® ePUR™ offers an ideal combination of new insulating chemistry and manufacturing know-how. Although the specific blowing agent depends on which vendor is performing the panel-forming process, it is important to note that the chemistry allows for the use of the latest, environmentally beneficial blowing agents—so-called "fourth generation" blowing agents that have the best ratings for both ozone-depleting potential (ODP) and global warming potential (GWP).

For life sciences packaging designers, the typical comparison has been EPS vs PUR, with the awareness that the higher performance of PUR is traded off with the lower cost of EPS. But the Envirocooler® ePUR™ changes this dynamic. Fig. 2 shows a comparison of Envirocooler® PUR and ePUR™ in a carton-size container over time. The ePUR™ insulation starts with a lower system R-value (and maintaining a lower temperature), and keeps that level of performance for much longer than conventional PUR.

Fig. 2

Average Performance of C-162 Container by Material



Cartons: the industry workhorse

The workhorse unit for temperature-controlled shipping, however, is the carton or case-size unit, with side dimensions of around 18-20 inches. These are the containers that are usually palletized for a bulk shipment from the manufacturer to the wholesaler/distributor, then broken down to typical shipments to pharmacy distribution centers or hospitals. The usual configuration of packaging components is an outer case of fiberboard, the insulation tub or panels with a removable hard lid or an open-cell PUR "plug", gel packs to maintain refrigeration temperatures, and the payload itself.

Fig. 3

Currently, the healthcare logistics industry is struggling to reconcile package performance (hours of temperature maintenance, such as 48 or 72 or more hours of temperature control) with trade lane distances (domestic, international) and carrier capabilities (refrigerated storage for customs clearance or for intermediate transfers). Yet another complication is the evolving national and international standards on temperature maintenance for so-called last-mile deliveries (to a hospital or doctor's office, for example) and for shipping controlled room-temperature pharmaceuticals.

When it comes to packaging design, Envirocooler® ePUR's combination of lighter insulation and better insulating performance presents a variety of options. The packaging engineer can opt for a carton design—dimensions and insulation panel thickness—that match existing carton designs; or use other dimensional options to increase the package usable volume, to increase its temperature performance, to decrease package dimensions while maintaining industry-practice performance—or variations of all three.

Initially, the Envirocooler® ePUR™ product line consists of four parcel-size shippers, with a broader range of 10 sizes total by early 2017. When compared to conventional PUR versions, all 10 ePUR™ solutions are smaller in size and feature thinner walls, which make them a drop-in replacement for competitive designs. The ePUR™ line of containers being offered initially have the following characteristics; a comparison with typical UR configurations is also shown:

Fig. 4

	Insulation thickness (wall/plug) (in.)	Outside Dimensions (in.)	Empty weight (lb.)
X-36	1.5/1.5	14.75x11.75x11.125	2.6
Equivalent PUR	2.0/4.0	15.75x12.75x14.25	4.0
X-90	2.25/1.5	17.50x15.50x17.875	5.7
Equivalent PUR	3.0/4.0	18.75x16.75x21.25	10.5
X-186	1.5/1.5	22.25x18.25x16.125	6.6
Equivalent PUR	2.0/4.0	23.25x19.25x19.25	10.0
X327	1.5/1.5	22.25x22.00x20.875	9.2
Equivalent PUR	3.0/4.0	23.25x23.00x24.00	14.0

Across the line, the Envirocooler® ePUR™ series shows lower weight and smaller dimensions, yet offer identical payloads and equivalent thermal performance. This is not an example of trading space for cost, it is simply using superior materials to ship the same payload for less cost.

It is important to stress that these designs are meant to address commonly used configurations in the industry today; higher performance (variations in payload size, or duration of temperature performance) are possible with ePUR insulation.

Logistics performance

A thorough analysis of container performance and economics depends on the specific temperature profile that a shipper will require, combined with the transportation cost practices of the carrier.

However, the Envirocooler® ePUR™ line already has two inherent advantages over conventional packages: lower actual weight (ranging between 35-46%, per Fig. 4) and smaller size (ranging between 20-27% reduction in DIM weight).

These specifications can have varying impacts on the cost of transportation, depending on the transportation mode and the carrier's policies.

One situation is worth highlighting: the use of DIM weight by major freight forwarders. For a typical price list involving second-day air, and assuming a total package weight (container plus payload) as shown in Fig. 5, the cost savings are potentially substantial:

Fig. 5

	Empty weight (lb)	DIM weight (lb)	2nd day air cost ($)	Savings (%)
X-36	2.6	11.6	$29.32	23%
Equivalent PUR	4.0	17.2	$38.22	
X-90	5.7	29.2	$60.22	21%
Equivalent PUR	10.5	40.2	$76.41	
X-186	6.6	39.4	$78.85	19%
Equivalent PUR	10.0	51.9	$97.30	
X-327	9.2	61.6	$107.81	20%
Equivalent PUR	14.0	77.3	$134.98	

Overall, Jarden estimates that total cost of ownership savings can approach 12% when the cost of materials, package assembly, shipping and disposal are taken into consideration. Supply chain managers should evaluate their own packaging needs, shipping lanes and carrier policies.

To approach these real-world program costs, consider a situation where a shipper is using a conventional PUR container that matches up with the X-90 unit as described above. Assume that 15,000 of the units are deployed annually for a domestic US shipment. Fig. 6 lists the key parameters in evaluating the economics of this scenario.

Fig. 6

	Competitive PUR	Envirocooler ePUR
Container Name	E-90	X-90
Purchase Price (ea)	$40.00	$40.00
Annual Volume	150000	150000
Empty Weight (lbs)	10.5	5.7
Inner Dimensions	12x10x13	12x10x13
OD Length (inches)	18.57	17.50
OD Width (inches)	16.75	15.50
OD Height (inches)	21.25	17.88
Wall Thickness (inches)	3.00	2.25
Plug/Lid Thickness (inches)	4.00	1.50
Incoming Containers (per pallet)	18	24
Incoming Freight Costs (per pallet)	$100.00	$100.00
Incoming Cost per Container	$5.56	$4.17
Domestic Dim Weight (lbs)	40.2	29.2
Typical Contents Weight (lbs)	15.0	15.0
Shipping Weight (lbs)	25.5	20.7
Negotiated Shipping Cost	$76.41	$60.22
Total Cost of Ownership	$121.97	104.39
Savings per Container		$17.58
Annual Savings		$2,636,833

As Fig. 6 demonstrates, the tens of dollars of savings for an individual shipment can add up to several million dollars in annual savings for a commercial cold-chain delivery program. As with previous comparisons in this paper, two equivalent packages are compared: similar capacities, but with lower weight and smaller dimensions achieved through the use of ePUR™. And because the refrigerant packout and payload sizes remain the same, this cost-saving change would not require any retraining or changes to product capacity. More demanding applications—such as extending operating life of a shipment to 72 hours or more, or shipping larger (pallet-size) quantities—could result in substantially more savings while offering superior performance.

Other applications under development include:

Pallet shippers for narrow-body aircraft

Wide-body aircraft are able to carry containers typically with a 48-in. height dimension, but those don't fit in narrow-body aircraft. Why this fact is of more than casual interest is that many of the world's airports are not able to land wide-body aircraft, but are limited to narrow-body planes. So, for a freight forwarder moving large quantities of life science materials to these airports, the choices are limited to shipping many cartons, or using the nearest wide-body-capable airport (which could be hundreds of miles away) and then employing ground transportation.

Because ePUR provides 30% better insulation R-value than conventional PUR (and nearly double that of EPS), pallet containers that are 30-in. high, but with thinner insulation thicknesses, are possible. Payload capacity can range as high as 10.9 cu. ft.

Insulation inserts for tote bins

The usual practice, once an order is placed from a local pharmacy to its primary distributor, is to fill a "tote bin" with the products in that order, then deliver, typically with a one-day turnaround, to that pharmacy. However, the increasing volume of life sciences products that require refrigeration, combined with regulatory requirements to maintain temperature control through this "last mile" delivery, call for taking measures to better protect products in totes.

Jarden Life Sciences is developing an ePUR™ insert that drops into the tote (which usually has a hard-plastic outer wall). The insert can provide better temperature maintenance during last-mile delivery, or, when combined with chilled gel packs, can maintain a refrigerated temperature range for the duration of most last-mile deliveries. The economics of last-mile protection are daunting: distributors work on razor-thin margins for making these deliveries, yet are obliged to ship to tens of thousands of locations daily in the United States.

For more information on Envirocooler® ePUR™ material and to understand how it can lower your total delivered cost, please contact us at http://jardenlifesciences.com/test-map/locations/contact/.